The Co-evolution of societal issues, technologies and industry regimes:
Three case studies of the American automobile industry

Caetano C.R. Penna

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SPRU – Science and Technology Policy Research
University of Sussex

I hereby declare that this thesis has not been, and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature: …………………………………………………

Caetano C.R. Penna

The capacity to construct a world is inseparable of the capacity to destroy it.
José Ortega y Gasset

Grau, teurer Freund, ist alle Theorie // Und grün des Lebens goldner Baum.
[Grey, dear friend, is all theory // And green the golden tree of life.]
Johann Wolfgang von Goethe in *Faust I* (Mephistopheles)

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Caetano C.R. Penna, DPhil in Science & Technology Policy Studies

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Summary

This thesis contributes to closing a gap in the field of science, technology and innovation (STI) policy research: despite many theoretical advances in the field, we still do not know why some urgent societal issues (or 'challenges') remain unaddressed, notwithstanding the technological advances that could potentially address them. In particular, radical technological innovations – innovations that depart from the established technological trajectory – would offer greatest potential to address societal challenges. While the source of radical innovations is often new entrepreneurial firms, *established* firms ('incumbents') are likely to play an important role in developing them because of the vast resources and complementary assets they possess. Incumbents however, face few immediate incentives to develop radical innovations in response to societal challenges.

The analytical puzzle of this thesis is thus to explain how, when, and why industries change (or not) their strategies (in particular, their technological strategy) in order to address a societal problem. This puzzle is disentangled into interrelated research questions:

A) How do societal issue-related pressures (on the incumbent industry) from different domains (namely, civil society, science, political arena, economy) evolve?

B) How does the incumbent industry respond to changing pressures around societal issues, in terms of technological, political, cultural and economic strategies?

C) In particular, when and why do industry actors decide to develop substantive technological responses?

To answer these questions, the thesis develops a new analytical perspective that combines insights from (a) issue life-cycle and issue *attention* cycle theories (from the Business & Society field) with (b) the so-called 'Triple Embeddedness Framework' and (c) concepts from business strategies, innovation management, corporate political strategies, and technology policy. This novel perspective represents an ideal-typical model of issue evolution ('issue life-cycle'). The model, which I call the Dialectic Issue Life-Cycle (DILC) model, is applied to three case studies of the American automobile industry's responses to various societal problems (local air pollution, auto and highway safety, and climate change). Combining qualitative and quantitative research methods in an original way, the case studies aim not only to investigate the validity of the framework, which also provides conceptual answers to the research questions, but also to further refine it and nuance the conceptual answers. By explaining how incumbent industry actors respond to societal challenges, this thesis ultimately contributes to the practical policy debate of how incumbents can be stimulated to develop radical innovations that help address societal challenges. ■

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List of acronyms and abbreviations

3E's	Triple 'E' framing (car safety): driver *Education*; road *Engineering*; and rule *Enforcement*
AAMA	American Automobile Manufacturers Association
ABS	Anti-lock Braking System
AFV	Alternative-Fuel Vehicles
aICE	advanced Internal Combustion Engine
aka	also known as
AMA	Automobile Manufacturers Association
APCD	(Los Angeles County) Air Pollution Control District
ASF	Automobile Safety Foundation
BEV	Battery-Electric Vehicle
Big Three	Chrysler, General Motors and Ford
BSE	Bovine Spongiform Encephalopathy
CAA	Clean Air Act (US)
CAFE	Corporate Average Fuel Economy
CARB	California Air Resource Board
CO_2	Carbon dioxide
CPA	Corporate Political Activities
CSR	Corporate Social Responsibility
CVC	Coalition for Vehicle Choice
DHEW	Department of Health, Education and Welfare (US)
DILC	Dialectic Issue Life-Cycle
DOE	Department of Energy (US)
DOJ	Department of Justice (US)
DOT	Department of Transportation (US)
EDV	Electric Drive Vehicles
EPA	Environmental Protection Agency (US)
FCV	Fuel Cell Vehicle
FFV	Flex-Fuel Vehicle
GCC	Global Climate Coalition
GSC	Grand Societal Challenges
HEV	Hybrid-Electric Vehicle
ICE	Internal Combustion Engine
IIHS	Insurance Institute for Highway Safety
IOR	Inter-Organizational Relationship
IPCC	Intergovernmental Panel on Climate Change
LAT	Los Angeles Times
MADD	Mothers Against Drunk Driving
MPH	Miles Per Hour
MUL	Mandatory (seatbelt) Use Law
NAS	National Academy of Sciences
NCAP	New Car Assessment Program

NHTSA	National Highway and Traffic Safety Administration (US)
NSC	National Safety Council
NTMVSA	National Traffic and Motor Vehicle Safety Act of 1966 (USA)
NYT	New York Times
OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PCV	Positive Crankcase Ventilation
PHEV	Plug-in Hybrid-Electric Vehicle
PNGV	Partnership for a New Generation of Vehicles
q.v.	*quod videre* ('please see', 'to be seen')
QLR	Quandt Likelihood Ratio
SAE	Society of Automotive Engineers
SOS	Stamp Out Smog (environmental group)
STI	Science, Technology and Innovation
STS	Science and Technology Studies
SUV	Sports Utility Vehicle
TEF	Triple Embeddedness Framework
TFP	Technology-Forcing Policy
TWC	Three-Way Catalysts or Three-Way Catalytic Converter
UNFCCC	United States Framework Convention on Climate Change
USABC	United States Advanced Battery Consortium
USPTO	United States Patent and Trademark Office
VMT	Vehicle-Miles Travelled
WBCSD	World Business Council for Sustainable Development
WP	Washington Post
WSJ	Wall Street Journal
ZEV	Zero-Emission Vehicle

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I. INTRODUCTION

Modern capitalist societies face serious environmental and social problems such as climate change, resource depletion and degradation, limited water and food supply, energy efficiency and security, obesity, diseases, demographic change, ageing and wellbeing etc. One important way to help address these societal issues[1] is the development of technical innovations. Indeed, addressing these problems – often referred to as 'Grand Societal Challenges' (GSC) – has become the focus of an emerging innovation policy agenda, best exemplified by 'Horizon 2020', the new *EU Framework Programme for Research and Innovation* (2014-2020).[2]

In particular, radical technological innovations – innovations that depart from the established technological trajectory – have the potential to offer greatest impacts in tackling societal challenges (Hoogma *et al.*, 2002; Hellström, 2007). While the source of radical innovations is often new entrepreneurial firms (Hockerts and Wüstenhagen, 2010; Ansari and Krop, 2012), established firms are likely to play an important role in helping address societal problems (Geels, 2012a), because of the vast resources and complementary assets they possess (Tripsas, 1997; Rothaermel, 2001). However, incumbent firms have little immediate incentive to address societal problems via radical innovations. The goal of this thesis is thus to develop a theoretical framework that explains how incumbents respond to societal challenges, and so to contribute to the practical policy debate of how they can be stimulated to develop radical innovations in response to these challenges.

I.1. RESEARCH MOTIVATION AND THEORETICAL GAP

Incumbent firms in an established industry often have little immediate incentive to address societal problems, particularly via radical innovation. The reason is

[1] "Societal issues" and "societal problems", as well as "social issues" and "social problems", are used as synonyms throughout this thesis. "Stages" and "phases" are also employed as synonyms.

[2] "Horizon 2020 reflects the policy priorities of the Europe 2020 strategy and addresses major concerns shared by citizens in Europe and elsewhere. A challenge-based approach will bring together resources and knowledge across different fields, technologies and disciplines, including social sciences and the humanities. This will cover activities from research to market with a new focus on innovation-related activities... Funding will be focussed on the following challenges: Health, demographic change and wellbeing; Food security, sustainable agriculture, marine and maritime research, and the bio-economy; Secure, clean and efficient energy; Smart, green and integrated transport; Inclusive, innovative and secure societies; Climate action, resource efficiency and raw materials." (European Commission, 2012, online)

twofold. Firstly, many societal problems are 'negative externalities' of the production or use of key incumbent technologies (Fischer and Schot, 1993), so that the cost of developing a radical innovation to address these problems is not reflected in markets and cannot be readily recouped by incumbent firms. Secondly, incumbents tend to suffer when radical innovations succeed, because they often disrupt their core competencies, capabilities and markets (Henderson and Clark, 1990; Anderson and Tushman, 1991; Ansari and Krop, 2012). Sometimes incumbents therefore not only do not innovate, but also put up active resistance to changes – leading to radical innovations – that could help address societal problems, through e.g. challenging scientific findings connected to the problem or lobbying against regulations.

Yet, past examples – such as major oil companies' development of biofuels to help cut CO_2 emissions (to mitigate climate change), automakers' promotion of safety devices to address road fatalities, DuPont's active promotion of technological alternatives to CFC to avoid the depletion of the ozone layer, or big electricity utilities' development of 'smart meters' to promote efficient consumption (and thus reduce CO_2 emissions) – show that at some point incumbents *can* change their strategies and become more seriously committed to developing and marketing technological solutions to a given societal problem. This raises the puzzle of understanding how, when, and why incumbent actors change their technological strategy to address a societal problem.

In theoretical terms, the thesis aims to address a gap in the science, technology and innovation (STI) policy research literature. More than 30 years ago, Richard Nelson (1977) outlined an evolutionary framework to analyse policy issues, in an attempt to understand why some urgent societal problems remained unaddressed, despite technological advances (a puzzle summed up by Nelson in the question, 'If we can land a man on the moon, why can't we solve the problems of the ghetto?'). "In Nelson's view, our ability to solve a particular social problem – including specifying what the problem is, as well as what might offer a solution – also requires a theory of the genesis of policy problems..." (Morlacchi and Martin, 2009, p. 574). Since the publication of his essay, STI policy research has matured, and yet, as Morlacchi and Martin (2009, p. 575) put it, "we still do not have a very satisfactory theory of social change. Our ability to improve social problems remains rather limited, and we do not know why we appear to have achieved only modest gains in relation to many societal problems".

Indeed, the contribution that the field of innovation studies can make to the new 'Grand Societal Challenges' agenda is currently limited, due to three reasons (cf. Geels and Penna, 2013). Firstly, the main approach used to tackle this new topic is the traditional innovation system approach (Mowery *et al.*, 2010; see the especial issue of Research Policy edited by Foray *et al.*, 2012), which has been originally developed in the context of the competitiveness agenda of the 1980s and 1990s (Morlacchi and Martin, 2009; Martin, 2012). While the innovation systems approach succeeded in tackling issues of *speed* of knowledge flows, *amount* of innovative outputs and their effects on *profitability* and *development* (Geels and Penna, 2013), the GSC agenda calls for theoretical approaches that tackle the issue of *directionality* of innovation (Stirling, 2007; Stirling, 2009). Secondly, innovation scholars concerned with societal challenges (e.g. Mowery, 2010; Mowery *et al.*, 2010; Foray *et al.*, 2012) tend to draw a parallel with mission-oriented R&D policies of the immediate post-Second World War, thus focusing on knowledge generation to the neglect of introduction of products in markets (Hargadon, 2010). Thus, firm and industry strategies are downplayed, particularly social and political strategies (Geels and Penna, 2013), because of the focus of innovation systems approach on economic issues. Thirdly, societal issues are not objective realities that only create 'new performance criteria' to be resolved by managers and engineers: societal issues are socially and politically constructed (Blumer, 1971; Spector and Kitsuse, 1973; Hilgartner and Bosk, 1988). For an issue to rise in the socio-political agenda, mobilization is needed (Lamertz *et al.*, 2003). Societal problems thus have complex dynamics, which impact on and co-evolve with the development of solutions (innovations).

This thesis therefore aims to make a contribution to the field of STI policy research by addressing this gap and contributing to the challenge-oriented agenda. The thesis puts forth a phase-model of societal problem evolution, which tries to capture the genesis process of problems, and which also incorporates strategic responses from the incumbent industry (and interactions with new entrants), highlighting, in particular, technological responses to a societal problem. In developing this model I take inspiration from a particular strand related to the STI field, namely, the *Greening of Industry* literature (see Kemp and Soete, 1992; Freeman, 1996), which has proposed stage models that conceptualized how industries respond to a particular kind of societal problem: environmental ('greening') problems. Differently from the innovation systems approach, this literature has paid particular attention to a certain issue of directionality: that of technologies and industries towards more environmentally-friendly configurations. However, the literature has limitations of its own, and therefore I combine it with a research strand from outside the STI field: *Issue life-cycle theory*, from the Business & Society field, which I review in the next chapter.

I.2. THE GREENING OF INDUSTRY LITERATURE[3]

In the past four decades, academic thinking on how industries respond to issues of 'greening'[4], represented by what may be referred to as the "Greening of Industry" literature, has changed substantially, in terms of main disciplines drawn upon, central focus, strategy implications, and level of analysis. Accordingly, the Greening of Industry literature may be stylized into three (at times overlapping) periods (Table I.1).

The first period, which began in the 1960s, saw the emergence of environmental problems such as air, water and soil pollution. Drawing on economics, these problems were conceptualized as externalities of technology change (Kemp and Soete, 1992) or market externalities, i.e. their costs were not reflected in prices, and therefore regulations would have to be enacted to internalize them (Fischer and Schot, 1993; see Crandall *et al.*, 1982 for a cost-benefit analysis of early regulations of externalities to automobile use). These regulations were thus seen as imposing additional costs to firms, which then had to engage in innovation that otherwise would not be demanded by consumers (who would ultimately bear the added costs) (Jaffe *et al.*, 2005). The implication of this economics perspective was that firms were expected to employ 'resistant compliance' strategies: they would engage in environmental innovation (basically, incremental innovations, such as pollution control technologies and waste

[3] This section expands on Penna and Geels (2012).
[4] 'Greening' means transforming products and processes (i.e. innovating) so that they become more environmentally friendly, resulting in e.g. less emission of pollutants or reduction of material disposal.

management techniques) strictly to comply with regulations (Fischer and Schot, 1993), but were not expected to (and often would not) move beyond compliance.

Table I.1: *Schematic summary of changes in the Greening of Industry literature*

	1960s-1980s	1990s	Late 1990s-2000s
Main discipline	Economics	Business and management	Organization theory, innovation studies, evolutionary economics, neo-institutional theory
Insights	Environmental innovation increases costs	Environmental innovation can create competitive advantage (win-win solutions)	Environmental innovation as longitudinal process, influenced by political struggles, public debates, economic considerations, technical capabilities
Strategy implications	Resistant compliance (to regulations)	Pro-active 'greening' strategies	Multi-dimensional strategic games
Level of analysis	Firms	Industries	Organizational field

Source: Author's elaboration based on Penna and Geels (2012)

The second period began in the 1990s, with new contributions coming from business and management scholars, e.g. via the *Greening of Industry Network* (created in 1991, see Fischer and Schot, 1993), and also innovation scholars (Kemp and Soete, 1992; Freeman, 1996). The level of analysis changed from single firms to industries and the perspective expanded to longer-term technical transformations and competitive dynamics (Fischer and Schot, 1993; Roome, 1998). Given the notion of 'resistant compliance' strategy from the previous period, research aimed to understand how to motivate not individual firms but entire industries to move beyond strict compliance and towards proactive environmentally-friendly strategies. This period thus saw the emergence of two central debates. The first one concerned the question 'does it pay to be green?': some scholars (most notably, Porter and Van der Linde, 1995) proposed that strategies such as environmental management systems, cleaner production processes and reduced material use could actually *reduce* costs to firms (i.e. that it 'pays to be green', because corporate economic performance would be improved). Pro-active 'greening' strategies thus would represent a 'win-win-win' solution (Elkington, 1994), benefitting corporations, consumers and societies (and their natural environment). Because the focus was on increased competitive advantage through reduced *costs*, the debate was still close to the economic perspective from the past. This debate on whether it 'pays to be green' goes on to this day (King and Lenox, 2001; Orsato, 2006; see Ambec and Lanoie, 2008 for a review of the debate), with many researchers testing the connection between environmental and financial performances, but without definitive answers (see Orlitzky *et al.*, 2003; and Molina-Azorín *et al.*, 2009 for two reviews of studies that attempted to test such connection).

The other debate that emerged in the second period of the greening of industry literature was about the 'antecedents' of corporate greening strategies. Two research strands emerged that tried to identify such determinants. One strand offered static lists of factors that would supposedly increase the likelihood of a firm to promote greening strategies (Henriques and Sadorsky, 1996; Fuchs and Mazmanian, 1998; Bansal and Roth, 2000). These lists included determinants that ranged from external factors – such as environmental policy, consumer demand and media attention – to organizational factors – such as top management style, corporate ethics and resources (technical, financial, organizational). This strand was subsequently criticized for a "failure to attribute degrees of importance to the identified influences" (Fuchs and Mazmanian, 1998, p. 195).

The second research strand took a more dynamic approach and proposed *stage models* of corporate greening, in which firms would start with non-compliance strategies, then move to compliance, and finally to pro-active 'greening' strategies.[5] This progress was thought to depend on changes in individual (CEO) attitudes and their socio-psychological characteristics (Roome, 1992; Winsemius and Guntram, 1992; Fischer and Schot, 1993). These corporate greening models were subsequently criticized for: (a) too much inward focus on corporate characteristics and CEO attitudes (Ghobadian *et al.*, 1998); (b) adhering to a linear model with deterministic (teleological) progression through stages

[5] Winsemius and Guntram (1992), for instance, conceived four stages in corporate environmental response (*reactive*, *receptive*, *constructive* and *proactive*). Roome (1992) distinguished five stages: (1) *Non-compliance* due to cost constraints or lack of long-term vision; (2) *Compliance* as legislation sets the agenda; (3) *Compliance-plus*, i.e. proactive integration of environmental management systems into business strategy (beyond law requirements); (4) *Commercial and environmental excellence*, when the company starts seeing 'good environmental management' as 'good management'; (5) *Leading edge*, when the company uses state of the art environmental management techniques. See Kolk and Mauser (2002) for a thorough review of stage models of corporate greening.

(Schaefer and Harvey, 1998; Kolk and Mauser, 2002); (c) prescriptive advocacy ('normativity') and moralistic bias, despite the difficulty in operationalizing such models (Schaefer and Harvey, 1998; Kolk and Mauser, 2002; Kallio and Nordberg, 2006). While I am interested in stage (or phase) models, which are an important way to conceptualize the temporal dimension of industry responses to societal/environmental problems[6], these caveats have to be taken into account when developing my contribution. Recent debates in the greening of industry literature provide suggestions as to how such limitations can be addressed.

In a review of stage models of corporate greening, Schaefer and Harvey (1998), for instance, recommended "that future research use broader, multi-dimensional theoretical frameworks, incorporating more detailed study of the institutional pressures and internal conditions and processes which shape individual companies' environmental strategy" (p. 119). These authors also remarked that not only pressures *for* environmental management should be considered by researchers, but also pressures *against* it. Thus, in the most recent period (from 2000 onwards), greening of industry scholars aimed to address previous criticisms by conceptualizing interactions between internal processes of corporate greening and external contexts (Schaefer and Harvey, 1998; Hoffman, 2001). Mobilizing insights from wider theoretical traditions such as evolutionary and institutional perspectives, organization theory and innovation studies, they aimed to develop multi-dimensional understandings of greening processes that would account for the multi-dimensionality of corporate strategies towards environmental problems (Roome, 1998; Schaefer and Harvey, 1998; Jones and Levy, 2007).

Hoffman and Ventresca (2002) introduced an organizational-field approach to conceptualize the "complex evolution of ideas, resources, social structures, and practices as *organizational* process that takes shape in broader, increasingly institutionally structured policy fields" (p. 2). They suggested that industry greening is a *longitudinal process* that involves corporate strategy, public debate and dialogue, political conflict as well as technical and economic dimensions. As

[6] While this literature has a strict focus on greening problems and related environmentally-friendly (product and process) innovations, I take the perspective that the insights it provides may be applied to other non-greening problems as well. This assumption will become clearer in Chapters II and III, when I review issue life-cycle theory and propose an original model of issue evolution, respectively.

Jones and Levy (2007) put it, in conclusion to a study of climate change strategies of big firms: "The position of firms is not merely for or against action on climate change, nor even along a continuum between those two extremes. Rather, a firms *[sic]* response to climate change occurs in many dimensions, including political, technological, organizational, financial and public relations components" (p. 429).

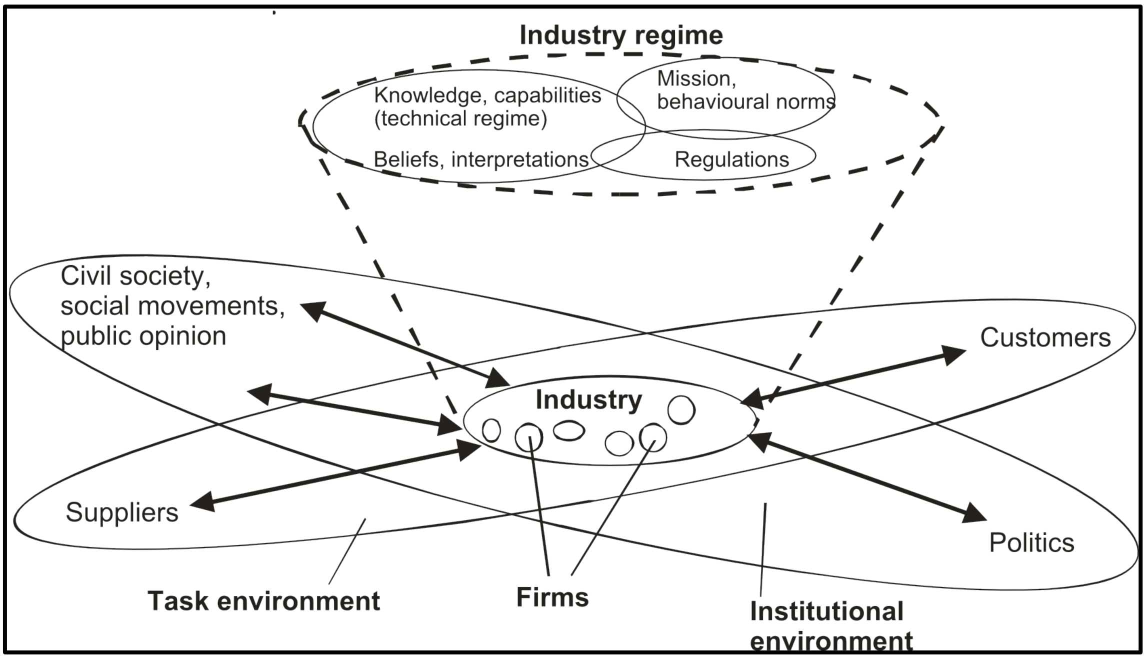
In light of these criticisms and advances, my contribution to the STI policy research will take two key insights from the greening of industry literature: that (a) environmental problems and industry response strategies progress through stages; and (b) this is a longitudinal, multi-dimensional co-evolutionary process at the *organizational-field level*, which calls for an approach that takes into account the relationship between corporate, industry and context dynamics. Here I suggest that these insights apply not only to 'greening' problems, but also to societal problems in general. Thus, my model of societal problem evolution and industry response strategies aims to be more general that strictly 'greening' models. The model I will put forth does not aim at 'managerial prescription' but to provide an analytical heuristic that can be used to make sense of empirical cases, based on which policy and strategy lessons can be drawn. My model also aims to avoid deterministic (teleological) progression through stages, through the incorporation of building blocks based on dialectical and life-cycle logics (Van de Ven and Poole, 1995). In this respect, I will incorporate insights and concepts from *issue life-cycle* models (developed by Business & Society scholars), which conceptualize how issues evolve and how firms-in-industries respond to policy issues. Because early models were also criticized for deterministic linearity, recent contributions have developed ways of overcoming this caveat.[7] Finally, by acknowledging the multi-dimensionality of the process and the dynamic interaction between industry strategies and contextual pressures (field-level interactions), my model avoids an inward focus, as well as environmental (contextual) determinism. To understand the interaction between contextual pressures and endogenous responses, I draw on an existing framework of industries in contexts.

[7] Moreover, as my review will show, the issue life-cycle literature offers insights into how societal problems are socially constructed, thus helping to avoid reification, an issue that also affects the Greening of Industry approach.

I.3. BACKGROUND FRAMEWORK OF INDUSTRY DYNAMICS: THE TRIPLE EMBEDDEDNESS FRAMEWORK (TEF)

The *Triple Embeddedness Framework* (TEF), developed by (Geels, 2012a), is a field-level model of industries in contexts, which conceptualizes industry-actors (firms) as embedded in two external environments and in an 'industry regime'. Schematically, the TEF is represented in Figure I.1.

Figure I.1: The Triple Embeddedness Framework of industries in contexts



Source: Geels (2012a)

Building on evolutionary economics, science and technology studies (STS) and neo-institutional theory, the TEF sees an industry as operating not only in a *task* environment – where it competes for market-share, profits etc. – but also in an *institutional* environment (Oliver, 1997), where competition is for *social fitness* (Powell, 1991). Hence, the industry can be seen as 'embedded' (Granovetter, 1985) in two environments that exert different selection pressures, which sometimes are connected to societal problems.

The third embeddedness is that of industry actors in an 'industry regime', which comprises *industry-specific institutions* that mediate perceptions and actions of firms in an industry towards the external environments (Geels, 2012a, p. 3). Geels (2012) proposes that this industry regime can be seen as consisting of four 'core elements': (1) *goals, values and mission*, which indicate the industry's societal purpose and business domain; (2) *beliefs and cognitive frames*, which mediate managerial interpretations of external environments; (3) *knowledge and* *capabilities*, which represent key resources for operational processes and innovation activities; and (4) *industry-specific regulations* that shape the industry's incentive structures. Following the insight from Giddens' (1984) structuration theory, Geels (2012) propose that industry actors' are not only *determined by* but also *shape* these industry-specific institutions: their response to contextual pressures is both enabled and constrained by the regime's core elements.

In an industry regime, all four core elements are interrelated, as indicated by the encircling in Figure I.1. One advantage of the industry regime concept – which builds on but is broader than the evolutionary economics' notion of technological regimes from Nelson and Winter (1982) – is therefore that it shows that technology development is related not only to knowledge and capabilities, but also to the industry's goals, values, mission, beliefs, cognitive frames and regulations. Thus, the industry regime concept makes it possible to distinguish and explain different types of technological/industrial change (Penna and Geels, 2012): (a) incremental change (minor changes in technology in accordance to prevailing knowledge and capabilities); (b) 'strategic reorientation' which entails more substantial (radical) changes (in technology and marketing strategy); and (3) 'strategic recreation', which *additionally* entails changes in core beliefs and values (Tushman and Romanelli, 1985). I expect that industry actors will employ more resistant strategies towards societal problems that require changes in core beliefs and values (Penna and Geels, 2012).

Furthermore, for the purposes of this thesis, the TEF is a useful background model of industry dynamics, because it allows for the conceptualization of multi-dimensional industry strategies in response to pressures connected to a given societal problem (indicated in Figure I.1 by the bidirectional arrows linking firms-in-an-industry to actors-in-the-environments). For instance, towards pressures stemming from the task environment, firms may employ *economic positioning strategies* (supply chain management, operations management, marketing etc.) (Porter, 1980) and *innovation strategies* (Tidd *et al.*, 2005). Towards institutional pressures, firms may employ *corporate socio-political strategies* (Schaffer, 1995; Mahon and McGowan, 1996; Hillman and Hitt, 1999; Oliver and Holzinger, 2008). These different types of response strategies will be incorporated to my model of societal problem evolution and industry response strategies. My model will therefore expand on the TEF as a background model to conceptualize how industry-specific institutions evolve over time in relation to a given problem.

I.4. RESEARCH QUESTIONS AND RESEARCH STRATEGY

I.4.1. Research questions

The analytical puzzle of this thesis is to understand how, when, and why industries change their strategies (the technological one, in particular) to address a societal problem. This puzzle is disentangled into interrelated research questions that I will address in the thesis:

A) How do societal issue-related pressures (on industries), from different domains (namely, civil society, science, political arena, economy), evolve?
B) How do industries respond to changing pressures around societal issues, in terms of technological, political, cultural and economic strategies?
C) In particular, when and why do industry actors decide to develop substantive technological responses?

I.4.2. Research strategy

To answer these questions, I develop a new analytical perspective that combines (a) issue life-cycle and issue *attention* cycle (q.v.) theories (from the Business & Society field) with (b) the Triple Embeddedness Framework and (c) concepts from business strategies, innovation management, corporate political strategies, and socio-cultural strategies. My novel perspective proposes an ideal-typical model of an issue life-cycle. I will confront this model with three case studies of the American automobile industry, and various societal problems (local air pollution, auto and highway safety, and climate change). The case studies combine qualitative and quantitative research methods in an original way, and aim not only to test the framework, but also to enable further refinements and the articulation of more complex paths for issue life-cycles.

The first two case studies are historical: they investigate the American automobile industry's strategic responses (a) to the problem of local air pollution, which is connected to the catalytic converter innovation and (b) to the problem of auto and highway safety, which is connected to many safety-related innovations, but most prominently with airbags. The third case study is contemporary and investigates (c) how the American automobile industry is responding to the problem of climate change. Here, an additional goal is to identify at which issue life-cycle stage this problem currently is. Chapter III will give more detail on case selection.

I.5. THESIS OVERVIEW

This thesis is divided in seven chapters, besides this introduction. Chapter II reviews issue life-cycle theory, and other literature that is relevant to help address some blind stops in this theory. Chapter III integrates the reviewed concepts into a coherent theoretical framework: the Dialectic Issue Life-Cycle (DILC) model. In the end of the third Chapter, I offer tentative (theoretically informed) answers to my research questions. Chapter IV presents the methodology that I will use to test the DILC-model. Due to my ontological and epistemological assumptions, I employ two complementary Process Theory methods: the narrative approach and the quantification approach. This Chapter also justifies case selection, and elaborates a case study protocol and analytical strategies. Chapters V to VII apply and test the model in three empirical cases: (1) *The issue of local air pollution and the American automobile industry (1940s-1980s)*; (2) *The issue of automobile safety and the American automobile industry (1900-2000)*; and (3) *The issue of climate change and the American automobile industry (1979-2012).* The concluding chapter offers my cross-case analysis, elaborates conceptual and nuanced answers to the research questions, makes explicit this thesis' contributions, discusses limitations of this thesis' research and contributions, and suggests areas for future research.

II. LITERATURE REVIEW

II.1. INTRODUCTION

In the introductory chapter, I articulated the motivation for my research and presented a gap in the STI field that my contribution aims at addressing. I also discussed the Greening of Industry literature, as a sub-branch of the STI field, from which I took two key insights: (a) greening (societal) problems and associated industry response strategies progress through *stages*; and (b) this progression represents *a longitudinal, multi-dimensional co-evolutionary process at the organizational-field level*. My contribution will develop a novel stage model of societal problem evolution and industry response strategies that take these insights as starting point.

Existing stage models of corporate greening cannot be directly applied to the analysis of such processes of problem evolution and industry response strategies, because they have important deficiencies: (1) they are prescriptive; (2) they have an 'internalistic' focus on firms; and (3) their stages are teleological. These are caveats that must be addressed for my model to go beyond existing stage models of the greening literature. The first deficiency is less of an issue for the model I will propose, because it does not have the ambition to prescribe policy measures to public authorities or corporate managers. Instead, I aim to develop a conceptual framework for the analysis of historical and contemporary cases of societal problems and industry responses. To avoid the internalistic focus (deficiency two), my model draws upon the second insight above, incorporating and building on the field-level framework of industry dynamics (the TEF) that I also introduced in Chapter I. The TEF should strengthen the analytical power of my model, by enabling a stage model that is neither inwardly geared nor biased towards contextual determinism. To address the third issue, I will build on issue life-cycle theory, which I review in this Chapter. My review will show that three generations of issue life-cycle theory – with increasingly sophisticated stage models – have been developed. Drawing on insights from issue life-cycle theory, I will propose a stage model of issue evolution and industry strategic responses that avoid a teleological argument by building on a 'dialectical dynamics' (which will be explained on page 43).

The goal of this literature review is therefore to raise insights for my model of societal problem evolution and industry response strategies from issue life-cycle theory in order to understand how technologies develop in response to societal problems. Yet, as my review will show, issue life-cycle theory presents gaps of its own; namely, it does not explain: (a) the shift towards substantive response by corporate actors, particularly how innovation strategies are deployed (and how technologies evolve) throughout the life-cycle; (b) how to quantify and depict an issue-life cycle (the issue life-cycle as a function of public concern or attention remained unspecified); (c) the interplays between firm-level and collective (industry-level) strategies.

To overcome these gaps, I propose bringing in conceptualizations from other literatures. Addressing point (a) is of particular interest in this thesis, and it actually offers an opportunity to combine STI theory with issue life-cycle theory; section II.3 therefore reviews concepts from technology and innovation management studies and from the flourishing literature on ‘technology-forcing policy’. Point (b) will be addressed with concepts from issue-attention theory (reviewed in section II.4), which also offer interesting qualitative insights that will be incorporated in my model. The third issue (point c) will be addressed with conceptualizations from the Organizational Institutionalism tradition about ‘interorganizational relationships’ and ‘corporate political activities’, which are reviewed in section II.5. While my goal is to contribute to the STI field, the conceptual model developed in this thesis is not only an extension to third-generation issue life-cycle theory but an original contribution to the Business & Society field as well.

II.2. ISSUE LIFE-CYCLE THEORY AND VARIOUS STAGE MODELS: A CRITICAL REVIEW

Issue life-cycle theory emerged in the 1970s in connection to the debate about Corporate Social Responsibility (CSR). The theory conceptualizes the progression of societal issues through time, with some stage models being developed as an aid to ‘issues management’, which refers to “the processes by which the corporation can identify, evaluate and respond to those social and political issues which may impact significantly upon it” (Wartick and Rude, 1986, p. 124). In his seminal book

Corporate Behavior and Social Change (1978), James Post explained the idea of 'issue life-cycle' as follows:

> *Public issues generally appear to pass through a series of phases which, because of their natural evolution, can be treated as a life cycle. Although an issue may not become obvious to us until it is highly politicized and on the verge of legislative action, there is in fact a long gestation period during which time much activity has to occur to make the issue a truly public one.* (p. 22)

I identify three generations of issue life-cycle theory and models that were developed since the 1970s. Table II.2 summarizes the main characteristics of these generations, which I label 'Emergent', 'Integrative' and 'Expansive', respectively. While the first generation offered first insights and intuitions, the second generation aimed at integrating these into a coherent whole, and the third generation expanded the theory with the incorporation of concepts from other disciplines.

Drawing on different academic disciplines, each generation attempted to address problems in previous conceptualizations. Similarly to the Greening of Industry literature (see Table I.1 in Chapter 1), the analytical level of these succeeding generations moved upwards to the industry level with the third generation of scholars. However, as I will show, the literature did not look at the interplays between firm- and industry-level strategies, and neither has the organizational-field level been incorporated into the literature. This presents an opportunity to analyse issue life-cycle dynamics within a field level framework, i.e. the field-level Triple Embeddedness Framework of industry dynamics. This is therefore the level on which I will concentrate when developing my stage model in Chapter III; yet, I will also conceptualize the relationship between firm-level strategies and industry dynamics.

Table II.1: Schematic summary of the three generations of issue life-cycle theory

	1st Generation: Emergent	2nd Generation: Integrative	3rd Generation: Expansive
Period	1970s-1985	1985-1990s	Late-1990s onwards
Key works	Ackerman (1973); Sethi (1975, 1979); Post (1978); Buchholz (1982); Buchholz *et al.* (1994 [1985])	Tombari (1984); Bigelow *et al.* (1991, 1993); Mahon & Waddock (1992); Wartick & Mahon (1994)	Mahon & McGowan (1996); Näsi *et al.* (1997); Bigelow *et al.* (1997); Wartick & Wood (1998); Gerde & White (2003); Lamertz *et al.* (2003); Rivoli & Waddock (2011)
Disciplines and theories	Political Science (Public Policy studies); Strategic Management	Issues Management; Strategic Management; Corporate Political Strategy	Symbolic Interactionism; Reputation Management; Stakeholder Theory (etc.)
Main themes/ focus	Corporate Public Responsibility; Corporate Social Responsiveness	Integration of corporate responsiveness with public responsibility	Further integration, plus multidisciplinary expansion
Level of analysis	Firms (and their managers)	Firms	Industry
Theoretical & Methodological gaps	a) Stages of issue life-cycle and stages of corporate strategies loosely coupled; b) Little explanation of the shift towards substantive response (e.g. technological strategy); c) Contextual determinism: managerial discretion constrained throughout the life-cycle; d) Too much emphasis on the public policy process and assumption that all issues follow the same cycle. Not clear about: how issues emerge (societal pressures as a black-box), what happens within stages and phase shift; e) Lack of attention to competing issues and to the relationship between multiple business strategies.	a) Little explanation of the shift towards substantive response (e.g. technological strategy); b) 'Lighter' contextual determinism: 'triggering events' still as autonomous pressures (for e.g. phase shift); c) Issue life-cycle as a function of public concern or attention unspecified (measurement issue); d) Little explanation of the interplays between firm-level and collective (industry-level) strategies. e) Lack of criteria for the (conceptual and/or empirical) identification of stages (methodological issue)	a) Little explanation of the shift towards substantive response (e.g. technological strategy); b) Little explanation of the relationship between an issue life-cycle and issue attention-cycles (measurement issue); c) Little explanation of the interplays between firm-level and collective (industry-level) strategies. d) Lack of explicit criteria for the (conceptual and/or empirical) identification of stages (methodological issue)

Source: Author's elaboration based on reviewed works[8].

[8] These works were selected through a citation analysis (using both the *ThomsonReuters' Web of Knowledge* and *Google Scholar*). I began with a backward citation analysis of works from the 1990s and 2000s (e.g. Bigelow *et al.*, 1991, Mahon and Waddock, 1992, Lamertz *et al.* 2003, Rivoli and Waddock, 2011) to trace the sources they refer to. These original studies included Ackerman (1975), Post (1978), Sethi (1975, 1979), and Buchholz (1982 – or other editions of this book/other works by Buchholz). I then made a forward citation analysis for these works to identify other relevant contributions to the development of issue life-cycle theory (e.g. Bigelow *et al.*, 1993, Wartick and Mahon, 1994, Rakich and Feit, 2011 etc.). This method resulted in a sample of models/works that, to my knowledge, represent the bulk of issue life-cycle theory.

II.2.1. The 1st generation of issue life-cycle theory (1970s-1985)

The first generation of issue life-cycle theory was developed by scholars from the *Corporate Social Responsiveness* tradition (Ackerman, 1973; Ackerman and Bauer, 1976; Sethi, 1979) and from the *Corporate Public Responsibility* tradition[9] (Post, 1978; Buchholz, 1982). These scholars attempted to move away from the prescriptive and normative orientation (Lee, 2008; Dentchev, 2009) associated with 'Corporate Social Responsibility' (CSR) (for a review of the CSR concept, see Carroll, 1999). It was also a reaction to criticisms by authors such as the economist Milton Friedman, who argued that the 'social responsibility of business' was to 'increase its profits' and who contended that responsibilities other than that would impose a costly burden on shareholders (Friedman, 1962).

Proponents of *Corporate Public Responsibility* argued that corporations had an economic responsibility *and* a public responsibility (Wartick and Cochran, 1985). The latter referred to a company's responsibility to tackle the secondary or consequential outcomes of its 'primary involvement' activities (the 'basic business functions', i.e. its economic tasks plus legal requirements) (Preston and Post, 1975; Preston and Post, 1981). These authors further suggested that the market provided direction for corporate decisions about primary involvement activities and that the *public policy process* provided guidelines for decisions related to secondary involvements (Wartick and Cochran, 1985).[10] The public policy process covered the formal and *informal* 'rules of the game' (Buchholz, 1982), to include "also the broad pattern of social direction reflected in public opinion, emerging issues, formal legal requirements, and enforcement or implementation practices" (Preston and Post, 1981, p. 57). The rationale behind the Public Responsibility approach was that secondary activities were important because through them a business enterprise could *change* the rules of the game (Bigelow *et al.*, 1990).

Scholars in the *Corporate Social Responsiveness* tradition also "intended to shift the emphasis away from social obligations and to social response processes" (Wartick and Cochran, 1985, p. 762); they put forth a pragmatic argument (Dentchev, 2009) for why business should act responsibly and respond to social

[9] See Wartick and Cochran (1985) for this classification of traditions.
[10] This conceptualization fits well with the perspective of industries as embedded in two environments, the economic/task and the institutional environment, which the TEF framework assumes, and will be explored in the next chapter.

demands: "unless social issues can be processed with reasonable speed, they may pile up and ultimately put the company in a position where it cannot function effectively in its traditional role as a producer of goods and services" (Ackerman, 1973, p. 95).[11] In fact, firms already actively managed societal issues and pressures stemming from them (Maurer, 2007), so that scholars began to study strategic response patterns of firms confronted with societal demands to develop a practitioners-oriented theory of corporate social responsiveness.

Those two approaches converged in their ambition to understand how firms exercise their 'legitimate right' to change the rules of the game (Buchholz *et al.*, 1994 [1985]) and effectively manage societal issues. A key tool developed were stage models of issue life-cycle and corporate response strategies. One of the first models of this kind was proposed by Ackerman (1973), who intended to illustrate "how a policy problem is converted into a managerial problem through the process of institutionalization" (p. 95). Ackerman contended that changing and increasingly demanding environmental conditions evolved through certain 'phases' that paralleled corporate response patterns. Despite his original insight, Ackerman's model was not fully specified, e.g. it did not explain how societal issues emerged in the first place and how they were translated into societal pressures directed onto the corporation (Maurer, 2007). More full-fledged models from the first generation were proposed by Sethi (1975; 1979), Post (1978) and Buchholz (1982). It is worth looking at these contributions in more detail, as they became the basis for the next generation of issue life-cycle models.

Sethi (1975; 1979) proposed a stage model of issue evolution that divided "the elapsed time between the emergence of a problem and its solution and ultimate elimination into four categories or stages: (a) pre-problem, (b) identification, (c) remedy and relief, and (d) prevention" (1979, p. 66). One of the important insights of this model is its 'identification stage', during which affected groups try to define (frame) the problem, identifying its causes and assigning responsibilities. "The definition of the problem may also involve the vested interest or value-orientation of a particular group. [...] What is a problem to one group may appear to be an obstruction to another" (Sethi, 1979, p. 69). The author here indicates two

[11] This argument somehow anticipates the 1990s' 'win-win' discourse about industry greening.

important phenomena that characterize initial stages of an issue life-cycle: (1) sense-making efforts, which lead to a problem framing; and (2) the potential of struggles between groups with conflicting interests regarding the problem, which, I propose, may translate into a 'framing struggle'.

Sethi (1975, 1979) also provided important insights about how companies respond to a 'legitimacy gap', which is "a gap between business performance and societal expectations" (Sethi, 1979, p. 65), and forms the basis for the emergence of a societal issue. Companies facing a legitimacy gap will first attempt to change public expectations/perceptions through public relations before it attempts to bring about substantive changes in business performance/operations (Sethi, 1979). Sethi also proposed a three-stage 'schema' for classifying corporate behaviour towards societal issues, in which a firm moves from (a) 'exploitative and defensive adaptation, with maximum externalization of costs', through (b) 'reactive adaptation', with limited internalization of previous external costs to (c) 'proactive adaptation', with anticipation of future environmental changes. The schema was however criticized for representing *generic stances* towards the external environment (Buchholz, 1982), rather than particular strategies in a given stage of an issue life-cycle (Näsi *et al.*, 1997; Maurer, 2007).

Post (1978) proposed that a public issue goes through four distinct stages: (1) the first stage is about the emergence of an *expectational gap* (similar to Sethi's 'legitimacy gap'); (2) in the *political stage*, actors begin to form coalitions and devise "strategies to shape the appropriate legislative context for the issue" (Post, 1978, p. 24); (3) in the *legislative (and implementation) stage*, regulations are enacted and implemented; and (4) in the *litigation stage*, the regulatory agency (or other public body responsible for implementing the policy) and regulated firms may take legal action against each other. Post (1978) suggested that the enactment of legislation in the third stage is the 'turning point' or 'high point' of the life-cycle process, because it publicly legitimizes a new set of societal expectations and institutionalizes the issue. After this high point, the issue can become highly publicized again if it reaches an implementation or litigation stage marked with controversy between business and governmental agencies (p. 25). So, the emergence of new conflicts may renew public and media interest.

Post (1978) also looked at corporate response strategies to societal issues and proposed that these go through three phases (which he does not directly relate to his four-stage issue life-cycle model): (1) 'awareness or cognizance of public issue' (e.g. environmental scanning, sense-making); (2) 'commitment to action'; and (3) 'selection and implementation of response'. And he offered two insights about corporate response to societal issues: (a) the second stage of strategic response involves a period of technical learning about the issue in question, and (b) the organization's previous history and characteristics play important role in determining current response strategies.[12]

Buchholz (1982) proposed a three-stage model of issue life-cycle: (1) 'Public opinion formation', when the issue is voiced by disadvantaged groups and activists; (2) 'Public policy formulation', when the initial ideas are translated into formal policies; and (3) 'Public policy implementation', when formal policies are implemented. This model has a similar logic as Post's (1978), but here the political and legislative stages are combined into the 'public policy formulation' stage, while the implementation of new laws is merged with Post's litigation stage into the 'policy implementation' stage.[13] Buchholz' argument was that policy-making is a political process that attracts media attention and is usually visible to the public, while implementing a piece of legislation is a technical process carried by regulatory agencies, which is less visible to the public.

Concerning response strategies, Buchholz (1982) and Buchholz *et al.* (1994 [1985]) described four 'generic response strategies or overall response patterns': (1) a generic strategy labelled 'Inactive': "In the inactive response pattern, business does not treat a public issue as within the domain of its concern, at least as far as changing corporate behaviour is concerned, and refuses to acknowledge that any change is necessary" (Buchholz *et al.*, 1994 [1985], p. 47); (2) a 'Reactive' strategy, which can be (a) negative (blocking issue progression) or (b) positive (accommodating the issue); (3) a 'Proactive' strategy (modifying external

[12] To this I add that the industry regime in which the organization is embedded also plays important role in determining response strategies. This insight will be further developed in Section II.5 and in Chapter III.
[13] This shows that there is no unique perspective on the issue life-cycle, and the specification of each stage will depend on the factors brought to the fore. In the model I will propose, the logics for phase definition and transition will be dialectical: the interplay between issue-related pressures and industry response strategies.

expectations through public relations or modifying internal structures of business performance); and (4) the 'Interactive' strategy, which is vaguely specified by Buchholz *et al.* (1994 [1985]), but seems similar to the third stage of Sethi's scheme.

Given the similarities between Sethi's and Buchholz' schemes, it is no surprise that the latter suffers some of the same problem as the former: it is loosely coupled with the stages of an issue-life cycle (and so are Post's schemes). However, Buchholz *et al.* (1994 [1985]) went one step further and identified specific strategies (or tactics) that companies employ throughout a three-stage issue life-cycle: (1) *communications strategy*, which targets the public opinion formation stage and aims at preventing the issue to move along its life-cycle, reducing the need for substantive changes in business operations; (2) *political strategy* – such as setting-up trade associations, lobbying or constituency building – to influence policy proposals; and (3) *compliance strategies*, including legal action or non-compliance and 'creating a new issue' (Buchholz *et al.*, 1994 [1985]), which targets the public policy implementation stage. This latter option of compliance strategy – 'creating a new issue' – may consist in reframing the issue or the new regulation to force the life-cycle back to the beginning (i.e. into the public opinion formation stage). Here Buchholz is hinting at the interplay between multiple issues and the effects of a competing issue on another issue's life-cycle.

Buchholz (1982) also proposed that managerial discretion over response strategies diminishes as the issue progresses in its life-cycle. This claim can be criticized, however, for embodying a certain type of 'contextual determinism', in which corporate strategic responses automatically followed from objective (reified) 'pressures' stemming from the external environment. As Lamertz *et al.* (2003) put it,

> *This objectification of issues is evident in the way their evolution is modeled as a function of public attention or public policy initiatives, and in the way in which social actors are modeled to detect or act in response to an issue at the various stages of its career. As a result, these models shift the emphasis away from the complex institutionalized system in which actors strategically formulate and propagate* [and respond to] *social issues…* (p. 83-4)

First generation models have also been criticized for two other reasons. First, these works place *excessive emphasis on the political context and the public policy* *process*, as if all issues were resolved strictly in the governmental arena (Bigelow *et al.*, 1993). Secondly, with societal issues reified, underlying societal pressures remained a 'black-box', and this early theory did not explain how issues emerge in the first place. Mahon and Waddock (1992) criticized early issue life-cycle theory for the assumption

> *...that all issues follow the same cycle, that all issues are resolved in the political-legislative-judicial* [i.e., the public policy] *arena, and that the progression of issues, while difficult to precisely time, all follow a similar curvilinear path through stages. What this approach fails to provide us is an understanding of what happens within each of the stages and how an issue moves from one stage to another.* (p. 22)

Furthermore, the excessive emphasis on the public policy process means that early models looked almost exclusively at single 'focal' issues[14] (Bigelow *et al.*, 1993), despite Buchholz *et al.* (1994 [1985]) early insight. Consequently, interactions with competing issues and the dynamic relationships between multiple business strategies (including 'primary involvements' strategies, i.e. economic and market strategies) were ignored (Mahon and Waddock, 1992). The second generation of issue life-cycle theory and stage models therefore aimed at addressing these problems, building on key insights from the early generation.

II.2.2. The 2nd generation of issue life-cycle theory (1985-1990s)

The problem of loose coupling of stages of issue evolution and stages of corporate response strategies can be explained by the fact that key contributions concerning the *issue side* had been developed by scholars working in the *Corporate Public Responsibility* research stream, while corporate response strategies were the main focus of scholars from the *Corporate Social Responsiveness* tradition. In the first generation, these two research streams were loosely coupled (despite the tardy contributions by Buchholz and colleagues, discussed above). The second generation of issue life-cycle theory aimed at combining them more systematically.

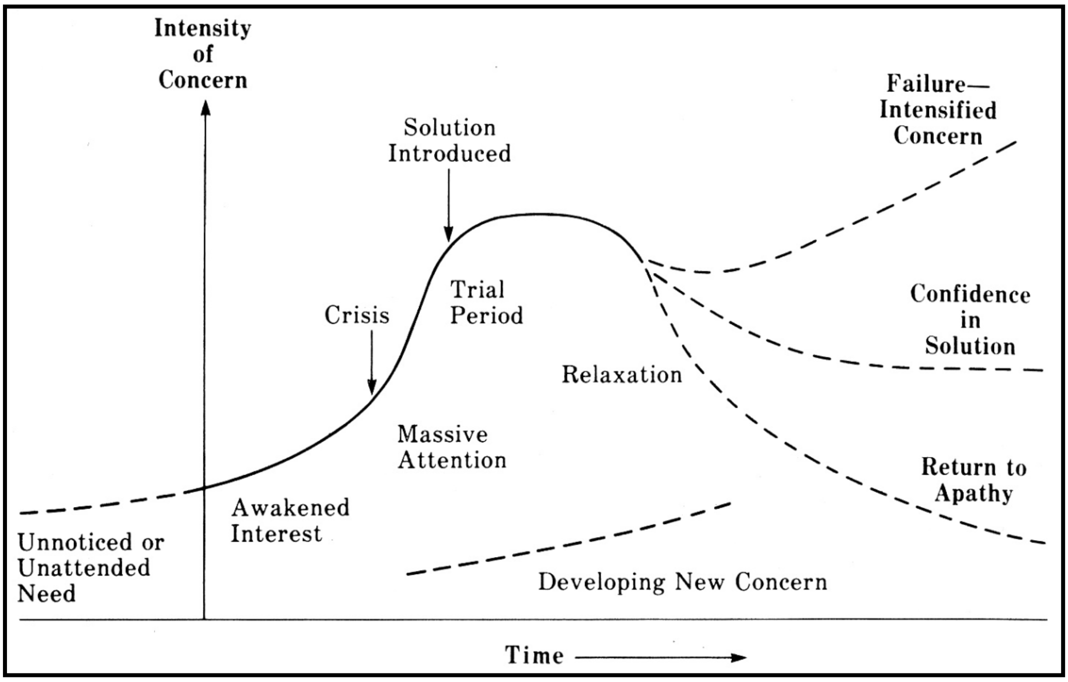
Most authors in the second generation of issue life-cycle models worked within the 'Issues Management' tradition (for a brief review of this tradition, see Wartick and Heugens, 2003). One of these authors was Tombari, who in 1984 published a textbook titled *Business and Society: Strategies for the environment and*

[14] 'Focal' issue (or problem) is the one whose evolution a given analysis attempts to explain. However, in the process of issue evolution, a focal issue will be influenced by 'competing' issues. This 'multiple-issue interaction' will be conceptually explored by second generation authors.

public policy, in which he "tried to summarize the state of the art of the strategic management process as it relates to socio-political matters" (p. vi). The goal was to integrate previous conceptualizations into a 'strategic issues management system', in order to "recognize environmental shifts, plan responses, and implement them effectively" in real world contexts (*idem*). Other authors also contributed to this integrative effort: here, I review in some detail the issue life-cycle models of Tombari (1984), Bigelow *et al.* (1991; 1993), and Mahon and Waddock (1992), which form the core of the influential second generation of issue life-cycle theory.

Tombari's (1984) textbook appeared one year before Buchholz and colleagues (1985)[15] published their contribution, but it is placed in the second generation because he does not focus exclusively on the policy arena (Mahon and Waddock, 1992), while the latter does. The author did not discuss issue life-cycle theory extensively (he dedicated only two pages of his 500-page long textbook to it), but provided a visual representation[16] of the life-cycle (Figure II.1) that reveals more than his discussion of the theory.

Figure II.1: Tombari's issue life-cycle



Source: Tombari (1984, p. 362)

[15] Buchholz *et al.* (1994 [1985]).
[16] Tombari attributes the authorship of the figure to William Royce of *SRI International*, who assisted him by providing research results and other data on socio-political planning in large multinational corporations (cf. Tombari, 1984, p. vi).

Six important insights can be derived from Tombari's representation (cf. Mahon and Waddock, 1992, p. 23-24). Firstly, his representation does not focus exclusively on the public policy process (there is no mention to political or legislative stages, for instance). Secondly, the representation can be interpreted as a five-stage model consisting of: (1) 'Unnoticed or unattended need'; (2) 'Awakened interest'; (3) 'Massive attention'; (4) 'Trial period'; and (5) 'Relaxation'. Thirdly, it indicates that the transition from phase 2 to 3 is marked by a sense of crisis, while the transition from 3 to 4 is marked by the introduction of a solution, which is the high point of the life cycle. Fourthly, *issues do not follow the same cycle*, which in his approach means that after a solution is introduced, life-cycle dynamics can continue after the 'Relaxation' stage (Mahon and Waddock, 1992) and the issue may follow three different paths: 'intensified concern', when the introduced solution is a failure; 'confidence in solution', when attention shifts away from the issue; or 'return to apathy'. A fifth insight is that *multiple issue life-cycles take place at the same time* (which in Figure II.1 is represented by the 'developing new concern' dotted line), implying that firms (have to) devise strategies to tackle multiple issues, each at different life-cycle stages. Finally, *the issue life-cycle can be seen as a function of the 'intensity of concern' devoted to the issue* – but 'intensity of concern' remained underspecified.

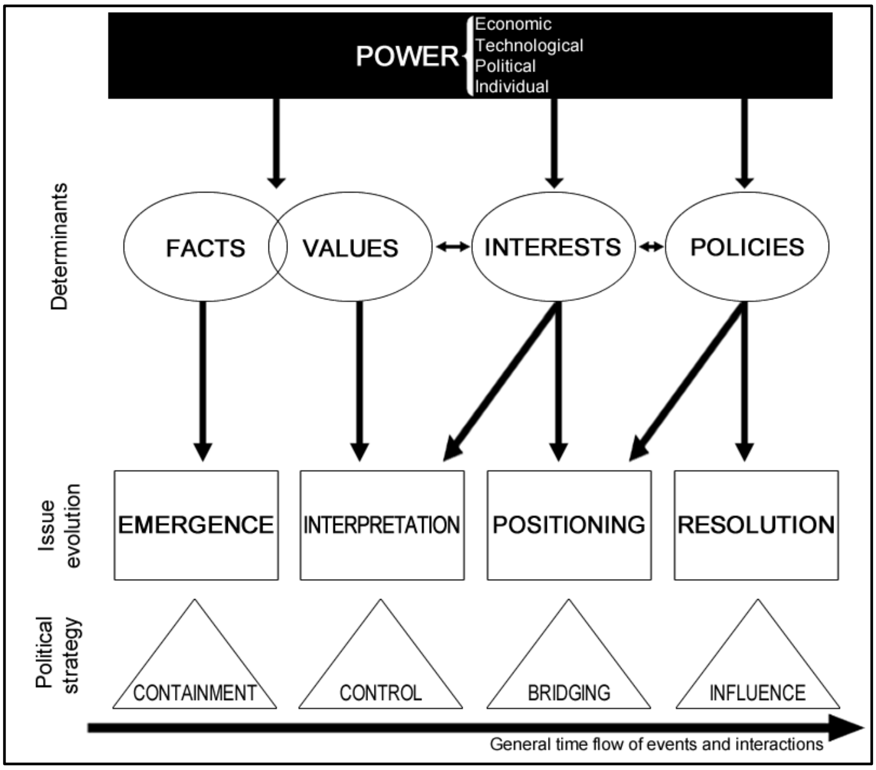
Although, Tombari opened the way towards tackling some of the gaps of the previous generation, he did not develop his model in depth, and did not explain how an issue emerges or why an issue returns to apathy. Notwithstanding, Tombari's insights provided the groundwork for the second generation of issue life-cycle theory.

Bigelow, Fahey and Mahon (1991). Despite his integrative efforts, Henry Tombari did not examine how firms' response strategies interact with issue life-cycles. This task was done by Bigelow, Fahey, and Mahon in a 1991 article (Bigelow *et al.*, 1991), where they proposed an issue life-cycle model that links issue evolution with political strategies, thus addressing the criticism that this link was not well specified in previous models. They argued that different kind of factors/determinants mark each stage of an issue life-cycle and lead to different response strategies.

> *Determinants are facts, values, interests, and policies. Stages of issue evolution are emergence, interpretation, positioning, and resolution. As an issue evolves, facts become increasingly less important as the issue is interpreted and positioned in the light of values and interests of key stakeholders. As it nears resolution, policies define the means by which it will be resolved. Because of these differences, the strategies for managing issue evolution also change. The different strategies are containment, control, bridging, and influence strategies. Power, defined from various perspectives (economic, market, technological, political, individual) is clearly recognized as having continuous influence on the entire process of the issue life cycle. As a consequence it is placed at the top of the process, with influence on all stages and determinants of issue evolution.* (Bigelow *et al.*, 1991, p. 3)

Their integrated conceptualization can be seen in Figure II.2. It goes beyond first generation models because, like Tombari's, it is not dependant on any single resolution arena. Secondly, the model recognizes that an issue evolution begins before actors have established their positions, and thus it throws some light onto the process of issue emergence and on the processes that define each stage. A third key feature of their model is hence the shift from a conceptualization based on *events* to one based on *processes*, which "leads to a reconsideration of the dynamic interplay between issues, strategies, and stakeholders" (p. 22). Because this is the most full-fledged issue life-cycle stage model of the second generation, it is worth examining it in more detail.

Figure II.2: Bigelow's *et al.* (1991) issue life-cycle with determinants and political strategies



Source: Author's elaboration based on Table 1.2 of Bigelow *et al.* (1991, p. 11)

- *Emergence stage:* The key characteristic of this stage is that issues are ill-defined, fuzzy and broad, with concerned groups not having fully grasped the implications of the facts that gave rise to the issue in the first place. The key determinants at this stage are *facts* (or events), which, after interpreted, are used in support of arguments and positions. "If facts are not known or cannot be determined, positions and arguments will be made on the basis of analogy, what limited information is known, or on sheer speculation" (Bigelow *et al.*, 1991, p. 7). The authors indicate that issues are socially constructed (although they do not refer to the social-constructivist literature), when they argue that facts are 'marshalled' by stakeholders to support their positions; but this point is not developed further and so the dynamics of issue emergence is not fully specified. The business strategy during the emergence stage is 'containment' of the issue, to prevent or direct its further evolution, through the manipulation of existing facts or the introduction of new facts. Possible tactics are (a) 'pre-emptive moves' to apparently or actually address emergent facts; (b) containment action to limit the number of stakeholders involved; and (c) symbolic acts to make the situation fuzzier (p. 12).

- *Interpretation:* This stage is marked by sense-making efforts. Stakeholders attempt to bring meaning to an emergent issue through "inferences and hypothesis about the source, cause, and solutions for an issue and its likely evolution and potential implication for themselves, enemies and allies" (Bigelow *et al.*, 1991, p. 5). Key determinants are the *values* hold by stakeholders concerned with the issue, their ethical orientation and their beliefs of what 'ought to be'. It is through values that facts are interpreted; as the life-cycle unfolds, both facts and values tend to get entangled as the basis for claims and arguments. 'Control' is the general business strategy in the interpretation stage, and it aims at controlling which positions are to be supported (and which are to be suppressed) by other stakeholders, because the dominant interpretation not only impacts but often determines the outcome (resolution) of the issue life-cycle. Tactics at this stage may be: (a) discrediting stakeholders with different interpretations to limit the number of interpretations and reduce the number of stakeholders involved or (b) marshalling support to preferred interpretations through the use of symbols and terminologies consistent with widely held values (framing tactics to gain legitimacy). The difference between the 'emergence' stage and the 'interpretation' stage is a bit fuzzy, because the first stage also contains interpretive efforts.[17]
- *Positioning:* "As stakeholders bring meaning to the issue, they develop positions that reflect not only their interpretations of an issue, but also the interpretations of competing stakeholders. Positioning, in which desired outcomes are developed, is clearly linked to interpretation" (Bigelow *et al.*, 1991, p. 5). Positions are also directly influenced by stakeholders' *interests*, which are pragmatic orientations (i.e. they do not necessarily reflect values/normative orientations) that "reflect what a stakeholder has to gain or lose" (p. 9). While previous strategies intended to prevent the issue to enter a 'highly charged public forum' (e.g. the governmental arena), if the issue enters the positioning stage, this cannot be done anymore. Consequently, the character of the corporate response strategy changes: it now aims at *(re)directing* the issue to a

[17] Sense-making is present in stage one, precisely because facts are meaningless unless interpreted. What can be argued is that in the second stage, sense-making and interpretation efforts are *systematically* articulated into an issue frame that clearly accounts for cause, effects and responsibilities. This is the idea that I develop in my model.

resolution arena where the corporation may have a 'comparative edge', by "bridging the gaps of interests or coalignment of interests among the key parties involved in the issue" (p. 18). The 'bridging' tactics are: (a) formation of coalitions or political alliances; (b) constituency building; and (c) financial contributions to attract supporters (cooptation).

- *Resolution:* The resolution is "the most political of the phases of the issue life cycle" (p. 19). Three distinct processes mark this stage: (1) the process through which stakeholders press for the adoption of their preferred solution (e.g. lobbying); (2) the actual process of defining the solution (e.g. legislating); and (3) the implementation of the chosen solution. The resolution stage is greatly determined by three components of policies: *existing policies*, which governs what and how can something be done; the *agreement that a new policy is necessary*; and the actual *content of the new policy* (including its implementation procedures). Corporate strategies will aim at influencing the latter two components: the perception that a new policy is needed (or not) and the content and execution of a new policy (if its approval cannot be stopped). Corporate political strategies that address the resolution stage are based on 'influence', "manifested in advocacy advertising, grassroots programs, planned demonstrations, the ability to produce media coverage for an 'event,' and the ability to turn out the vote" (p. 19). Strategies to influence the implementation of the policy often draw on technical expertise (e.g. expert witnessing, release of technical reports).

Despite the model's comprehensiveness, some points remain open. For instance, the authors still claim that corporate discretion diminishes throughout the life-cycle, based on the argument that, as the issue evolves, it gains in clarity and specificity, so that in the resolution stage, it is very well defined. In earlier stages corporate strategy can aim at determining what the issue is, but in the resolution stage "[w]hat remains to be determined is how to respond" (Bigelow *et al.*, 1991, p. 20). In my view, however, this argument does not always hold, since it is possible that corporate strategies may aim at *reframing* the issue or the policy to force the life-cycle back to the beginning. When the issue reaches its resolution stage, the formal policy institutionalizes a framing, and therefore it becomes *more difficult* to reframe the issue. It does not seem to be the case, however, that managerial discretion is automatically constrained, but that the *effectiveness* of some strategic options are higher or lower depending on the life-cycle stage (e.g. it is possible to adopt a denial strategy in all phases, but in the resolution stage this option may not be as effective as in the emergence stage).

Thus, Bigelow and colleagues still present a 'light' form of contextual determinism. But they explicitly recognize that different issues do not follow the same life-cycle: "issue evolution as a process may not be dissimilar to the process of unstructured decision making (Mintzberg *et al.*, 1976). The stages may all appear, but the order may change based on a number of contingencies" (Bigelow *et al.*, 1991: 23). I believe this is a crucial insight for avoiding a teleological construct, and so I will develop it further in my model and case studies. Yet, despite this recognition, and also the recognition that one issue life-cycle is influenced by developments connected to another issue, the authors do not explore these points further, nor do they explain the development of substantive responses (such as technological change) to address an issue (which, it must be said, was not within the scope of the paper).

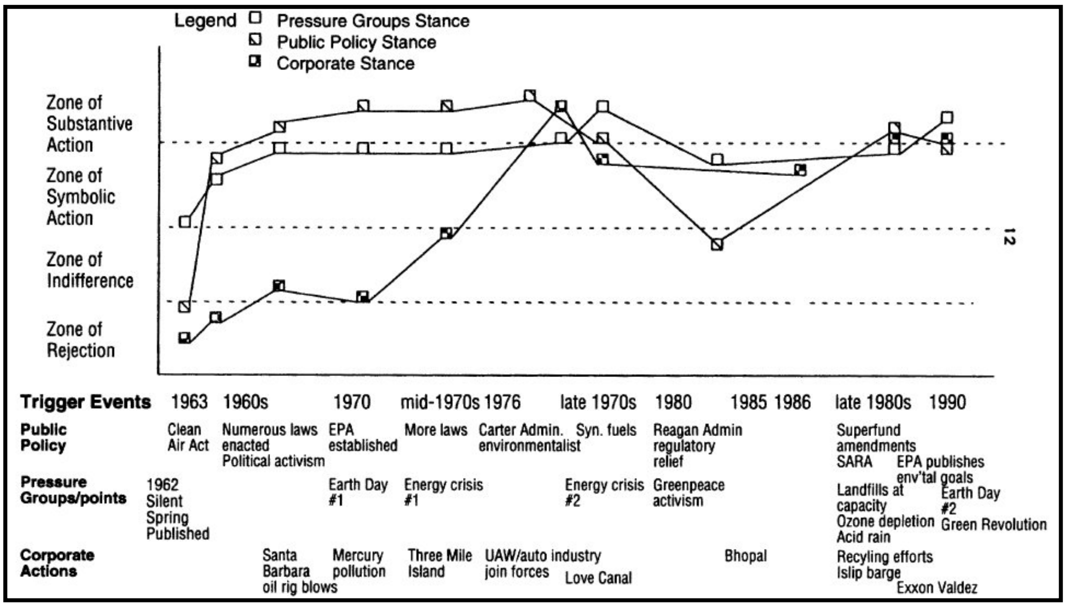
In summary, Bigelow's and colleague's model addresses several previous theoretical gaps: (a) it couples issue life-cycle stages with patterns of response strategy; (b) it shifts away the exclusive emphasis on the public policy process, by acknowledging that actors will attempt to solve the issue before it gets to the political arena; and (c) it proposes that distinctive processes (or phenomena) mark each stage of an issue life-cycle. However, four points remained unaddressed: (a) it does not fully specify the dynamics of issue emergence and of phase shift; (b) it does not address multiple-issue interactions throughout the life-cycle (which can be viewed as an empirical question); (c) it does not examine the development of substantive (e.g. technological) responses to the issue; and (d) it does not explore alternative issue life-cycle paths (i.e. life-cycles in which the phase order differs from the proposed linear order 'Emergence-Interpretation-Positioning-Resolution'). Some of these points were addressed by other works from the second generation.

<u>Mahon and Waddock (1992)</u> explicitly dealt with *substantive and symbolic responses* to societal issues by business, but without looking at innovation or technological strategies. In this work, the integrative character of the second generation of issue life-cycle theory is evident. The authors conceptualized the issue life-cycle by combining three perspectives of 'social issues management': (1) the 'public policy perspective' (i.e., the *Corporate Public Responsibility* tradition); (2) the 'corporate strategy perspective' (i.e., the *Corporate Social Responsiveness* tradition); and (3) the 'pressure group perspective', which the authors associate with the work of Kingdon (1984) and his multiple-streams model of policy agenda-setting. Before examining Mahon's and Waddock's framework, I therefore briefly explain Kingdon's model.

Building on the 'garbage-can' model of decision making (Cohen *et al.*, 1972), Kingdon argued that the policy-making process does not follow a linear logic in which the emergence of a problem is followed by the development of solutions. Instead, problems and solutions represent relatively independent dynamics in their own 'stream' of development. Kingdon's model thus consists of three 'streams': (1) the 'problem' stream; (2) the 'policy' (solution) stream; and (3) the 'politics' stream. The first stream represents the relative development of public issues (problems). The second consists of the portfolio of policies (and proposals) to deal with the array of problems in need for solution. And the third stream represents the political environment, which at different points in time present a more favourable climate for the passage of policies ('policy windows'). In Kingdon's model, a 'policy entrepreneur' (or advocate) plays the role of coupling the multiple streams when a window of opportunity is opened either in the politics or the problems stream. Policy entrepreneurs are visible participants in the agenda-setting process who articulate a condition as a problem and couple it with a solution.

Mahon and Waddock (1992) refer to Kingdon's model as the 'Pressure or Interests Group Perspective', because they see it as taking the perspective "of the pressure and interests groups from which policy entrepreneurs operate" (p. 24). The authors thus depart from Kingdon's conceptualization in that they do not see policy entrepreneurs as independent agents: policy entrepreneurs may come from government sectors, but also from social movements ('pressure groups') or from corporations and their trade associations ('interests groups) – "the three primary stakeholder groups that will ultimately deal with business-related social and public issues" (p. 25). A second departure is that they do not see the streams as fully independent (for a similar interpretation, see Elzen *et al.*, 2011), because policy entrepreneurs and other stakeholders may actively work within the different streams to promote or suppress an issue. With these modifications, Mahon and Waddock (1992) arrive at an 'Integrated Issue Life-Cycle Model' (Figure II.3) that combines the three perspectives, and which they apply to 'the environmental issue' in the USA.

Figure II.3: Mahon's and Waddock's (1992) Integrated Issue Life-Cycle Model



Source: Figure 2 in Mahon and Waddock (1992, p. 26)

The key insight from this model is that the life-cycle stage at which a given issue is will depend on the stance taken by the stakeholders toward the issue[18], which is what Figure II.3 depicts. The model "illustrates the position of each group with regard to its degree of rejection, indifference, or acceptance of the issue as relevant to its affairs" (Mahon and Waddock, 1992: 25). The integrated framework adapts Barnard's (1938) concepts of 'zone of rejection', in which an issue is not considered at all by the stakeholder; 'zone of indifference', in which the issue begins to be recognized, but no particular compulsion to act is felt, and 'zone of acceptability', in which actions are taken. A key insight that comes from Mahon and Waddock

[18] I will take this insight one step further, by proposing that the general stage of the issue life-cycle depends on the interaction between those exerting pressure and the industry, i.e. on the dialectical interaction between stakeholders.

(1992) is that the acceptability zone is actually divided into two: a 'Zone of symbolic action' and a 'Zone of substantive action'.

> *Symbolic action involves attempts to 'frame' an issue, giving it meaning to a group or groups whose values and ideologies are congruent with that framing. This is fundamentally a process of reinterpretation of the interpretation of events proposed by other actors. Substantive action, in contrast, involves definitive moves that attempt to actually change or deal with the existing situation in specific, identifiable ways. It often demands the expenditure of resources (money, equipment, personnel, etc) to minimally show progress in resolving the actual problem identified.* (Mahon and Waddock, 1992, p. 27)

These categories of symbolic and substantive action is consistent with Sethi's (1978) insight that companies facing a legitimacy gap will first attempt to change public expectations/perceptions through public relations (i.e. engage in symbolic action) before it attempts to bring about substantive changes in business performance/operations (substantive action). Indeed, Mahon and Waddock (1992, p. 28) hypothesize that "stakeholders will tend first to opt for the agenda shaping and setting activities of symbolic action. When symbolic action does not work, then substantive action becomes necessary (or mandated or otherwise forced)". This insight throws light into the process of technology development in response to a societal issue, as such strategy demands substantive 'expenditure of resources' and represents 'progress in resolving the actual problem identified'. I will draw on this insight when developing my model.

Although the description of what goes on within each phase of an issue life-cycle was not the main goal of the paper, their conceptualization also throws light onto the process of issue emergence: "it is the pressure groups and interest networks that are responsible for 'leading' the development of symbolism to which management and legislators must respond. In many instances it is pressure groups who are responsible for the symbolic or framing activities surrounding an issue, offering the first interpretation of events that call for attention" (Mahon and Waddock, 1992, p. 29). The idea is that the emergence of an issue is connected to the role played by activists/pressure groups in articulating the issue through symbolic action. Corporate and/or public policy actors will get involved with the issue not because some external events or objective conditions force them to act, but because they either accept the urgency that pressure groups attach to facts and events or because they reject such symbolism. Thus, this integrated conceptualization moves away from contextual determinism, although this does not stand out very clearly in Figure II.3, which seems to imply that 'trigger events' drive the different stakeholders into the different action zones. A particular problem with Figure II.3 is that the authors did not specify how the issue life-cycle can be measured, nor how it can be assessed that an issue has moved from one 'zone' (stage) to the other. Although their representation appears to be objectively constructed, the authors did not present the methodology behind it.

A strength of this integrated perspective is that it rejects the notion of a unique, linear life-cycle, because "issues can move from 'on the agenda' to 'off the agenda'" (Mahon and Waddock, 1992, p. 28), meaning e.g. that an issue may enter a legislative stage when it is on the governmental agenda but then return to an interpretation stage if a stakeholder succeeds in attaching new symbolism to emerging facts and events. This idea was fuller explored by Mahon and colleagues in the paper reviewed next.

Bigelow, Fahey and Mahon (1993) aimed at clarifying "what factors affect the path an issue takes" (p. 18) and proposed a typology of issue evolution. Because one of the identified factors that affect an issue life-cycle pathway is 'competing issues', the paper also sheds light on multiple-issue interaction. The analysis takes as starting point the integrated model of issue-life cycle and corporate political strategies (Bigelow *et al.*, 1991), which is characterized as the 'normal'/linear issue life-cycle, and identifies four 'forces' that may cause deviations from it:

1) Facts: The emergence of new facts – such as critical events, technological breakthroughs, scientific theories, economic crises etc. – may affect an issue evolution (through the interpretation ascribed to them by stakeholders). For instance, facts "may diffuse an issue that has already become public by recasting it" (Bigelow *et al.*, 1993, p. 21). Facts may also serve as triggers that "galvanize public attention and catapult an issue onto public agendas, before all stakeholders have interpreted it [or] solidified positions" (p. 22).
2) Stakeholders: Stakeholders may affect the issue life-cycle in two ways: (a) when new stakeholders get involved with the issue or old stakeholders do

not get involved anymore, positions may change; and (b) through strategic action, stakeholders may press the issue forward or stop its evolution.

3) Other issues: Multiple issues compete for public, political and corporate attention. Thus, the emergence of new issues acts as new facts that affect the evolution of a focal issue. Moreover, policies to tackle other issues may also affect the focal issue's evolution, e.g. by 'resolving' it before the resolution stage.
4) Scope of focal issue: If the issue has a large scope (if it is 'not well bounded'), then it may be subject to constant reinterpretations, so that its life-cycle goes back and forth, but a definitive resolution is never reached.

The authors argue that:

> *These four factors operate individually and collectively to influence an issue's evolution. Some issues do move sequentially through all of the stages. However new facts and other issues may create a need for stakeholders to reinterpret issues and subsequently redefine their positions. The inflexibility of some stakeholder positions may stymie attempts to achieve resolution. It may be argued that the 'normal' path assumed by most models of issue life cycles is in fact the least likely to occur.* (Bigelow *et al.*, 1993, p. 23)

Bigelow *et al.* (1993) propose five pathways in addition to the linear/normal cycle, divided into two categories: 'unidirectional' pathways and 'recursive' pathways. The unidirectional group includes three categories: (a) the *stopped* path, which happens when the life-cycle comes to a halt, i.e. the issue is not resolved and neither does it re-emerge (it 'dies out'); (b) the *interrupted* path, when the life-cycle stops for a period, then the issue re-emerges in the stage where it stopped until it reaches resolution; and (c) the *skipped* path, when the issue skip stage(s) and reaches resolution. The recursive group includes two categories: (d) the *cyclical* path, when the issue cycles back and forth through stages until it reaches resolution; and (e) the *enduring* path, when the issue cycles back and forth but the resolution is elusive. Table II.2 summarizes the impact of factors on the issue life-cycle in this 'typology of issue evolution'.

This typology represents an important step not only for understanding how different issues may follow different life-cycles pathways, but also for understanding the interaction between multiple issues. The typology brings about two implications (cf. Bigelow *et al.*, 1993, p. 26-7). One (managerial) implication is that response strategies are dependent upon the issue pathway (past and future/anticipated), which offers different entry points for intervention. The second implication is that the typology offers a template for "studying how the factors individually and collectively drive each issue path, what the differences are across the paths… […] Guided by an understanding of the broad contours of these paths, empirical longitudinal research can delineate and document the evolution of issues" (Bigelow *et al.*, 1993: 27). This is a suggestion that, to my knowledge, has not been empirically explored yet and, thus, I aim at tackling it in this thesis through a longitudinal, historical case study.

Table II.2: A Typology of issue evolution: impact of factors on paths

	Facts	Stakeholder	Other issues	Scope of issue
Normal	Additional facts do not interfere with evolution	Stakeholder actions do not interfere with evolution	Other issues do not interfere with evolution	Issue bounded, amenable resolution in some specific arena
Unidirectional				
Stopped	New facts emerge that render it a nonissue	Stakeholder actions successful at stopping issue	Other issues usurp attention	Issue bounded
Interrupted	Same as stopped; new facts emerge that reintroduce issue	Same as stopped; issue regain salience for stakeholders	Same as stopped; other issues resolved or stopped, attention returns to original	Issue bounded, amenable resolution in some specific arena
Skipped	Crisis occurs or new facts emerge that galvanize attention	New stakeholders enter that press issue forward	Outcomes of other issues push issue along path	Issue becomes well defined quickly
Recursive				
Cyclical	New facts cause reinterpretation of issue or reassessment of positions	Stakeholders entering and exiting cause issue to move backward and forward	Other issues act similarly to new facts	Issue is not well bounded, subject to reinterpretation, shifting positions
Enduring	New facts constantly entering and altering face of issue	Same as cyclical	Same as cyclical	Issue is not bounded

Source: Table 2 in Bigelow *et al.* (1993, p. 25)

However, an important caveat that prevents the direct application of this typology to empirical case studies is that it does not really explain the 'normal' pathway, as if an issue would naturally and deterministically follow a normal life-cycle that is 'armoured' against facts, stakeholders, other issues and the issues' changing scope. Thus, the typology is based on a deterministic view of a normal issue life-cycle, which furthermore does not include a discussion of (a) symbolic and substantive responses, the innovation process and the development of technological solutions; (b) how to empirically 'measure' and represent issue life-cycles (methodological issue); and (c) the interplays between firm-level, industry-level (collective) and field-level dynamics.

Thus, despite important insights, the discussion above showed that the second generation left four unaddressed questions (cf. Table II.1): (1) little explanation of how (and why) the shift towards substantive response takes place in an issue life-cycle (nor how the technological strategy is deployed throughout); (2) a 'light' form of contextual determinism remained, with the dynamics of phase shift unspecified and the process of issue emergence still unclear (even in 'normal' life-cycles); (3) the issue life-cycle as a function of public concern or attention remained unspecified (measurement problem); and (4) little explanation of the interplays between firm-level and collective (industry) strategies. Another gap, which could be seen as related to points (1) and (2) above, and which was particularly visible in the study by Mahon and Waddock (1992) is: (5) authors from the second generation did not specify criteria for the conceptual and empirical identification of stages, which can be seen as a methodological gap in issue life-cycle models.

II.2.3. The 3rd generation of issue life-cycle theory (late-1990s-2011)

The transition from the second to the third generation of issue life-cycle theory (late 1990s/early 2000s) saw a proliferation of works that applied models of issue life-cycle to empirical case studies. While some of these studies just tested the framework and had no theory development ambition, e.g. Gerde and White (2001; 2003)[19], others also had theoretical relevance. Näsi *et al.* (1997) offered suggestions for the development of the theory, and so I review it next. I also review below theoretical works from the third generation.

Näsi, Näsi, Phillips and Zyglidopoulos (1997) tested not only issue life-cycle theory, but also what the authors call 'legitimacy theory' (essentially, the *Corporate*

[19] Gerde and White (2003) applied issue life-cycle theory to the issue of auditor independence and the response of the auditing & accounting industry. It is worth noting their finding that a single person (what may be referred to as 'activist', as opposed to a pressure group) may act as an issue champion at early stages of an life-cycle, but trigger events seem to be necessary to create an window of opportunity for advancing the issue (cf. Kingdon's model, discussed in the previous subsection).

Responsiveness perspective associated with the work of Sethi), and stakeholder theory (Freeman, 1984; Clarkson, 1995). Of particular interest is their discussion and assessment of issue life-cycle theory, which, they argue, "remains a deterministic theory: outside groups call for change, and change eventually occurs" (Näsi *et al.*, 1997, p. 304). The determinism is also implied by the fact that "[issue] life cycle theory [...] allows the least managerial agency of the three theories" (p. 305), because of its claim that managers' discretion diminishes over the life-cycle of an issue. The authors compare the degree of 'issue specificity' of the three theories, and conclude that source and specificity of the focal issue is taken as a given in life-cycle theory (i.e. issues are reified). Näsi *et al.* (1997) test the three theories in a case study of four forestry companies' strategic response to public issues. The authors concluded that issue life-cycle stage models apply over long periods of time. Yet, they found that patterns of strategic response throughout the life-cycle fluctuated back and forth, from higher to lower and back to higher degree of commitment to address the issue, due to moderating economic factors (in other words, issues stemming from the task environment in the TEF).

Moreover, the authors found that managerial discretion is not automatically constrained over an issue life-cycle: the same portfolio of strategies is available throughout all stages. In conclusion, Näsi *et al.* (1997) argued that "issues are not floating about, agitating for change, but are connected to stakeholder groups who apply pressure... If a stakeholder group can sustain pressure on the organization over time, [...] then the life cycle curve seems to generally apply" (Näsi *et al.*, 1997: 317). Hence, in contrast with the typology of Bigelow *et al.* (1993), stakeholder actions do interfere with issue evolution even in a normal life-cycle – or, in other words, the normal life-cycle also depend on stakeholders' strategies. The authors also make suggestions for future research, two of which I will follow in developing my model of issue life-cycle: (a) that future research should look both at organizational and *interorganizational* political strategies; and (b) that a better understanding of how issues emerge is necessary, requiring "a more developed sense of institutional processes... [...] Concepts such as institutional field and interorganizational domain are closely related to the processes that produce issues, and current research in the area would gain from a closer connection to these theoretical areas" (Näsi *et al.*, 1997, p. 319). Despite being suggested fifteen years ago, to my knowledge, such a connection has not been established yet, and thus I aim to make it by drawing on concepts from the *Organizational Institutionalism* literature and on the field-level *Triple Embeddedness Framework*, on which I build to integrate the different building blocks that I raise in this Chapter.

Bigelow, Arndt and Stone (1997) present an issue life-cycle that combines the models by Buchholz (1982) and by Post (1978) and applies it to corporate (political) strategies of the health care industry. The authors add an 'anticipatory' stage that precedes issue emergence, resulting in a four-stage model: (1) Anticipatory[20] (2) Emergence; (3) Enactment; and (4) Implementation. They further identified appropriate (political) responses at each stage: (1) Goodwill strategy (e.g. corporate donations and community outreach, to gain public legitimacy) and assessment strategy (e.g. environmental scanning and sense-making, in order to be prepared if an issue emerges); (2) Communication strategy (e.g. constituency building, advocacy advertising, press releases, and other formal publications, with the goal of presenting the organization's position and influencing public opinion or to create an organized group of people that may influence subsequent stages); (3) Information strategy (e.g. expert witnessing or technical reports, to influence the content of legislation being introduced) and 'political' strategy (e.g. lobbying or financial contributions, also to influence legislative content or to prevent the enactment of legislation); and (4) Compliance strategies (e.g. negotiation of implementation terms, litigation, legislative relief or non-compliance).

A key difference with the conceptualization suggested by Bigelow *et al.* (1991) is that this one seems to consist of general strategic categories, while the latter appears to be more practical tactics. This work further advanced the understanding of corporate response, highlighting aspects that take place in different stages of an issue life-cycle. However, to systematically incorporate corporate responses into my model, I use these more advanced conceptualizations together with insights from other literatures (reviewed in Sections II.5 and II.6).

Mahon and McGowan (1996). An alternative conceptualization of the interplay between managerial strategies and tactics and the stages of issue life-cycles had been offered by Mahon and McGowan (1996, p. 41-3). They propose a four-stage

[20] The label 'anticipatory' seems appropriate for a stage in a corporate response model. For an issue life-cycle stage, maybe 'pre-issue' would be better.

issue-life cycle which is similar to Bigelow's and colleagues (1997), despite the different labels: (1) Introduction; (2) Growth; (3) Entry into a specific arena; and (4) Resolution. Appropriate political tactics for each stage are respectively: (1) Containment/Advocacy; (2) Containment/Advocacy (again); (3) Arena manipulation; and (4) Policy adaptation. The existence of an 'Entry into a specific arena' stage, which is proposed as a way to avoid the focus on a single arena (normally, the public policy arena, as in previous models), differentiates this scheme from others. The idea is that corporate political response in the 'growth' stage will aim at directing the issue to the preferable arena[21]; and after the issue enters a given arena, corporate actors may aim at influencing the way in which it is addressed there. In the fourth stage, corporate actors may aim at appealing to a different arena (e.g. appeal regulatory/legislative action in the judicial arena) or at influencing the way the resolution is actually implemented.

Another commonality between Mahon and McGowan (1996) and Bigelow *et al.* (1997) is that both indicate that firms are confronted with the choice of responding to an issue alone or in association with other firms. Bigelow *et al.* (1997, p. 55) argue that, during the 'enactment' (legislative) stage, individual firms *may* deploy their own political strategies, but "collective action is often necessary [...] for two reasons": firstly, legislators are more likely to attend to arguments that are voiced by a large constituency. Secondly, industry associations are likely to be more effective in lobbying policy-makers, because they have a more complete knowledge about the public policy and the legislative process.

Despite this insight, the interplays between individual firms' strategies and collective responses is not integrated in Bigelow's and colleague's model (1997). But Mahon and McGowan did suggest that the decision of whether to engage in political activities alone or with others is "a function of the type of impact that the issue has on the organization" (1996: 63). They propose three categories of issues: (a) technical issues (which impact upon core technologies and distinctive competencies); (b) administrative issues (which arise from the way an organization manages physical and human resources); and (c) institutional issues (which put into question the legitimacy of a firm or industry). The authors propose that:

[21] Hilgartner and Bosk (1988) list a number of arenas for issue resolution, such as the media (TV, press, radio, and, nowadays, the Internet), private foundations (e.g. trade associations), congress, judicial courts, local forums (churches, community associations) etc.

> *Technical issues* [...] *because of their intimate tie to individual firm distinctive competence, may be dealt with best on an individual basis,* ***unless a key aspect of this competency is distributed industry-wide****.* [...] *...a change that affects the distinctive competency of the entire industry as a whole would demand an industry-wide response. Administrative issues suggest that industry responses are more likely, with occasional cooperation among and between several industries. Finally, institutional issues can demand either individual* [when one firm's legitimacy is questioned] *or industry* [when the industry's legitimacy is questioned] *response dependent on the specific issue.* (Mahon and McGowan, 1996, p. 65-6 – **my emphasis**)

Despite representing a key advancement in issue life-cycle theory, in my view these conjectures do not *fully* explain the corporate choice of acting alone or collectively, as the authors argue that both choices are possible for all issues, and more light needs to be shed on the interplays between firm-level strategies and industry-level strategies. For instance, collective action may depend on the stage of the issue life-cycle (Hillman and Hitt, 1999). In order to fully take into consideration the factors that impact on this decision and incorporate them into my novel model, section II.5 will highlight key insights and concepts from selected works of the Organizational Institutionalism tradition.

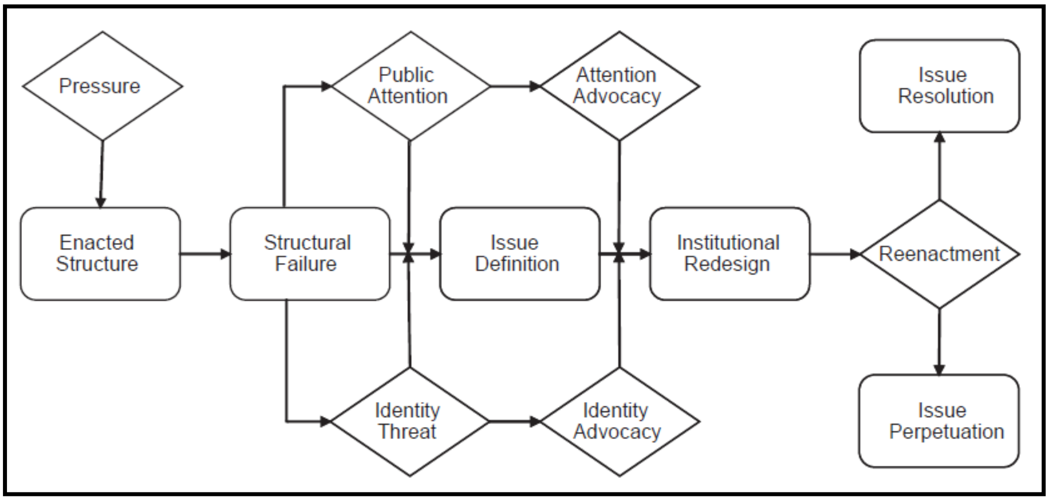
Wartick and Heugens, 2003. A new wave of conceptual issue life-cycle theory emerged in the mid-2000s, partially fuelled by the publication of a 2003 special issue (Volume 6, Number 1) of the journal *Corporate Reputation Review* on issues management. The editors (Wartick and Heugens, 2003) review the status of issues management theory, concluding, rather gloomily, that many models of issues management were non-academic; that the number of academic publications on the topic had been declining since the early 1990s; and that the research community was diminishing, because scholars were moving to stakeholder management theory. To revive the issues management tradition, they suggested, among other things, "infusing orthodox issues life cycle research with theories from other social sciences" (p. 13), in order to overcome its shortcomings. Let me elaborate on this suggestion, which I aim at following.

The editors firstly recognize the lack of agency in issue life-cycle conceptualizations and its failure to show how various actors actively shape issue evolution – what I have been referring to as 'contextual determinism'. To address this, they recommend the integration of institutional theory in issue life-cycle models – my model will make use of this suggestion and draw on the *Organizational Institutionalism* literature and the TEF. Secondly, "[a]nother problem that has haunted the issue life cycle literature for decades is that these models have been silent about the underlying mechanisms that *cause* the sudden upswings and gradual downturns in the amount of public attention a particular issue receives" (Wartick and Heugens, 2003: 14 – *emphasis* in the original). To address this issue, I propose that a more systematic integration of qualitative aspects of issue-attention cycle theory into a stage model of issue life-cycle, following the insights of Lamertz *et al.* (2003). This theory will be examined in section II.4, revealing insights also for tackling what I have been referring to as the 'measurement issue' (how to quantitatively measure and depict an issue life-cycle).

Lamertz *et al.* (2003), in the same special issue, develop an issue life-cycle model that takes a different approach to address the problem of contextual determinism, offering many relevant insights into an issue evolution process. Particularly, the authors give more attention to framing and interpretive processes in emergence of issues, a topic previously under-addressed. They criticize 'orthodox' issue life-cycle frameworks for their tendency "to reify social problems by granting them an existence that is quasi-independent from actors [...] and [...] cultural institutions" (Lamertz *et al.*, 2003, p. 83) and for the 'linearity' of such frameworks: "The main source of discontent is that issues often fail to progress along predictable lines, and deviate frequently from the linear, sequential path suggested by evolutionary frameworks" (*ibid.*). To tackle these caveats, the authors draw on *Symbolic Interactionism* (or 'Constructivist' theory) and on natural history models of social problems (Blumer, 1971; Spector and Kitsuse, 1973). Their model aims at "understanding [...] how the behavior of social actors is affected by the context and constraints of their social environment, while simultaneously illustrating how these actors can shape their social environment through strategic communication and interest advocacy" (Lamertz *et al.*, 2003, p. 90). The authors take a key premise from these sociological works: "social problem exists primarily in terms of how it is defined and conceived in society" (Blumer, 1971, p. 300).

Although their objective was to avoid the 'linearity' of issue life-cycle models, the proposed symbolic interactionist framework can be interpreted as a (linear) stage model (cf. Lamertz *et al.*, 2003, p. 84) affected by mediating factors ('attention' and 'identity'), consisting of five stages (see Figure II.4): (1) accumulation of pressure on the 'enacted structure'; leading to (2) a 'structural failure' of the 'enacted structure'; then to (3) 'issue definition'; followed by (4) 'institutional redesign'; and finally reaching (5) a 'Re-enactment' stage (either 'Issue resolution' or 'Issue perpetuation'). It is worth explaining this framework in some detail.

Figure II.4: A Symbolic interactionist framework of issue evolution



Source: Figure 1 in Lamertz *et al.* (2003, p. 85)

In their framework, an issue emerges when a 'structural failure' (or 'sense-making crisis') of the enacted social structure takes place.

> *A core assumption of this framework is that social interaction requires an enacted social structure…* […] [that] *include*[s] *the rules of conduct and the role expectations for participants in the social structure. Rules and roles do not determine behavior but act as interpretive frames that are a basis for sense-making.* (Lamertz *et al.*, p. 2003: 84)

A failure of the enacted social structure occurs as a consequence of the accumulation of non-routine situations (environmental/contextual pressures), for which social actors are not prepared, because the existing interpretive frames cannot explain these non-routine situations (or events). While the structural failure *per se* does not lead to the emergence of an issue (i.e. the failure is a necessary but not sufficient condition), it may be created because of variation in the way different actors make sense of external events, their causes and consequences.

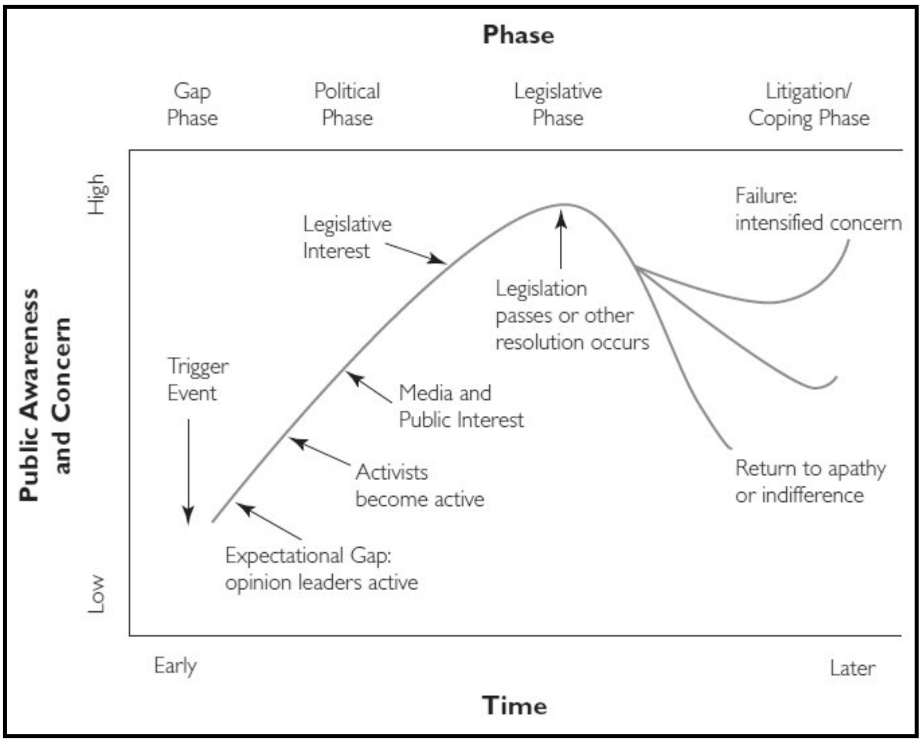
One source of cognitive variability is the different domains from which actors borrow concepts to make sense of these non-routine events. Thus, "social actors in a field compete to assert an interpretation of the sense-making failure – an *issue definition* – that is consistent with their private interests" (*ibid.*, p. 86 – *emphasis* in the original). The authors propose that two variables moderate the emergence of competing interpretive frames: (1) level of *public attention* to the issue (higher levels of public attention lead to higher levels of private attention and thus to deliberate issue definitions consistent with each actor's interests); and (2) the extent to which the structural failure implies an *identity threat* to the social actor, especially if other actors' interpretations threaten another actor's identity (the threatened actor will reaffirm its identity by promoting a competing interpretive frame).

As a consequence of this conceptualization of how an issue emerges, an issue will *evolve* by means of (what I call) a 'dialectical process' of shifting balance of power amongst actors concerned with the failed structure. Power and framing struggles over the meaning of external events will happen until an *institutional redesign* takes place. This may happen either (a) through the actions of a dominant actor who persuades or coerces "its peers into adopting its solution preference" (*ibid*., p. 88) or (b) via appellation to an external (public or private) authority. The issue moves to the institutional redesign stage because of actors' mobilization: different actors will actively raise attention to the issue and their preferred definition ('attention advocacy') to receive support from others (peers or external authorities); or they will engage in 'identity advocacy', i.e. appeal to "like-minded advocates that that can help them exercise control over the other parties in their environment" (Lamertz *et al.*, 2003, p. 89). Through mobilization, negotiation and advocacy an 'institutional redesign' plan is proposed. If actors misinterpret the meaning of the redesign plan, or if it fails to restablish an 'enacted structure', then the issue will be perpetuated (i.e. a structural failure persists, actors engage in issue redefinition etc.).

While the model may still be understood as 'linear' (which is a real possibility for issue evolution, as proposed by Bigelow *et al.*, 1993), Lamertz *et al.* (2003) *do* address the problem of contextual determinism (or teleology) of previous models and throw light on the process of issue emergence, because, in their model, actors are not triggered to action through critical events: "key social actors construct a social issue through interpretation of key events. [...] In this [symbolic interactionist] framework, issue evolution is therefore less a natural process of fluctuating public attention and more a social process of constructing and negotiating meaning in a context of ongoing social relations and transactions..." (Lamertz *et al.*, 2003, p. 84). Public attention is not just out there, but actors actively engage in the manipulation of public attention to advocate their preferred issue framing. The relevance of the 'symbolic interactionist framework' is not so much its "superior explanatory power" (*ibid.*, p. 91), but its highlighting of the importance, for evolution of issues, of (a) framing and social-construction of issues; and (b) public attention. In relation to the latter, it seems therefore appropriate to take stock of issue-attention theory (see section II.4).

Rivoli and Waddock (2011) show however that the 'natural history' models (which Lamertz and colleagues criticize) are alive and well, and still being improved upon. The authors use issue life-cycle theory to explain why the substance of responsible corporate behaviour changes over time. Their conceptualization of the issue life-cycle (Figure II.5), which clearly resembles Tombari's (1984 – cf. Figure II.1), consists of four phases: (1) Gap; (2) Political; (3) Legislative; and (4) Litigation/coping. While the labels are similar to stage models from previous generations, the actual discussion reveals important insights, which I list below.

Figure II.5: Rivoli's and Waddock's (2011) Public Issue Life Cycle Model



Source: Figure 1 in Rivoli and Waddock (2011, p. 91)

- The role of triggering events in starting the life-cycle: "The trigger event (or institutional 'jolt') is an event that draws public attention to a given issue, thereby activating the issue life cycle" (Rivoli and Waddock, 2011, p. 90). [From Lamertz *et al.* (2003) one could add that framing struggles and *disagreement over the meaning of triggering events* is also necessary for issue evolution.]
- The role of 'pioneering activists' – or 'opinion leaders' – in raising the issue (gap phase): "...the initial stage of the evolution of a public issue involves early or pioneering activists seeing a gap between desired and actual practice" (p. 90). [At this stage, the expectational gap is held *privately* by a few concerned individuals.]
- 'Activists become active': The advocacy of pioneering activists attract attention and support from the public and other stakeholders, so that 'ignoring' the issue is no longer a viable response by concerned organizations (*ibid.*, p. 91). Thus, the expectational gap becomes public when activists enter the process (transition from first to second stage). [This advocacy activity is akin to the process of 'transforming private troubles into public issues' that constructivist authors Spector and Kitsuse (1973) proposed as characteristic of the second stage of the natural history of social problems.]

- Media and public interest: if media and public concern is sufficiently raised and reach a 'threshold', legislative interest may be attracted to the issue [i.e. high media and public attention – an indicator for public concern (see Section II.4) – marks phase shifts].
- Issue framing process: The negotiation for a dominant issue framing takes place during the political and the legislative stages (the latter being marked by debate and compromise). "Framing is an important part of the process of institutionalization, [...] because ideas facilitate or constrain the policy and other behavioral choices that are later made by providing rationales for action (or inaction). [Some authors] characterize this interactive framing process as 'theorization,' a process that helps explain the causes and effects, as well as why an issue has taken the shape that it has" (*ibid.*, p. 92). [Science may play an important role in the framing process, because different stakeholders and organization draw on "scientific research [...] to establish the viability of their claims" (Schneider, 1985, p. 220)[22].]
- Move from individual to collective action: when the issue enters the legislative stage, firms [that may previously be acting collectively to defend their shared interests] begin to 'move at different speeds' regarding the issue at hand, because "early movers can take strategic initiatives that distinguish themselves from other companies" (Rivoli and Waddock, 2011, p. 94). [This move may be understood as one of the characteristics of the implementation stage: as the issue becomes institutionalized, it begins to affect the competitive environment, so that firms tend to compete with one another for a better position.]
- The issue may be resolved in two ways: "First, the behavior may spread and become common or accepted practice, even though it is not legally required. Second, the new behavior may become compulsory through a change in laws or regulations. Often, a behavior first becomes accepted practice, and *then* become legally required" (Rivoli and Waddock, 2011, p. 94 – *emphasis* in the original). [This is similar to Kingdon (1984) idea that problems and solutions develop in semi-independent streams, so that the appearance of solutions may actually elevate a problem to the top of the decision agenda. In Ravoli and

[22] Schneider (1985) provides a review of social problems theory of the constructivist tradition.

Waddock (2011), the emergence of new practices (solutions) makes the enactment of a new legislation more feasible "especially because companies incurring extra costs to adopt progressive practices have an incentive to have these costs applied to their competitors" (p. 101). This insight is also explored by the technology-forcing policy literature, which I briefly review in section II.3.]

- Issue institutionalization and public attention: if the issue does not attract sufficient public attention, it is less likely to become institutionalized. (Rivoli and Waddock, 2011, p. 95).

While Rivoli's and Waddock's conceptualization provides interesting insights into processes occurring within different stages and into phase shifts, the reliance on the level of public attention sometimes appear to camouflage the *processes that lead to surges* in public attention (i.e. purposive action by different stakeholders), so that the model returns to some light form of contextual determinism. Thus, as my comments between brackets above already indicated, and agreeing with the contention by Lamertz *et al.* (2003, p. 91) that "no single model of issue evolution" has yet fully captured the complexities of an issue life-cycle, I argue that it is through the combination of insights from different stage models of issue life-cycle and corporate responses – plus the incorporation of elements from other theories – that a 'big picture' model of the overall process may be built. Furthermore, neither Rivoli and Waddock (2011), nor other authors contributing to the third generation of issue life-cycle theory explicitly defined criteria for the (conceptual or empirical) identification of different stages. One could interpret elements in Figure II.5 as qualitative indicators that a given stage has started, e.g. the opening of an 'expectational gap' and actions by 'opinion leaders' would indicate that the issue has emerged (first stage, or 'gap stage', as labelled by Rivoli and Waddock); the fact that 'activists become active' would indicate that the issue has moved to a 'political stage'; increasing 'media and public interest' would then ensue and precede the move to the 'legislative stage' etc. Nevertheless, this is a possible conjecture that can only be implied from the figure, and therefore a methodological issue remains, because no author from the third generation proposed criteria for the identification of stages.

Taking on the challenge of developing a big picture model, and following suggestions from recent contributions, I review next important concepts from other theories in order to overcome three gaps that remain open in the third generation of issue life-cycle theory: (a) the shift towards substantive response by corporate actors, particularly how innovation strategies are deployed (and how technologies evolve) throughout the life-cycle (section II.3); (b) how to quantify and depict an issue-life cycle (i.e. the relationship between an issue life-cycle and issue-attention cycles) and the incorporation of attention dynamics in an issue life-cycle model (section II.4); and (c) the interplays between firm-level and collective (industry-level) strategies, including the systematization of types of political activities in the life-cycle (section II.5). The final gap that I aim to tackle, namely, (d) the lack of explicit criteria for the (conceptual and/or empirical) identification of stages (methodological issue) will be dealt with in Chapter III, where I will propose conceptual (qualitative) criteria for the identification of phase shifts, and in Chapter IV, where I will propose the adoption of a methodology that makes use of both qualitative and quantitative approaches to identify empirical stages (the qualitative approaches will focus on attention indicators and draw on the discussion in section II.4 about attention dynamics).

II.3. INNOVATION MANAGEMENT AND THE STRATEGIC USE OF TECHNOLOGY

II.3.1. Introduction

The previous section highlighted important insights for understanding how societal issues evolve, but also revealed gaps in the issue life-cycle literature, which need to be addressed in order to answer the question of how incumbent industries respond to societal issues. One gap is particularly relevant given my goal of making a contribution to the STI research field: namely, that issue life-cycle theory have not fully explained why incumbent industries shift from symbolic to substantive responses to a societal issue. In particular, innovation strategies and technological developments remain a blind spot in the theory.

An important reason why this topic remained under-addressed is that issue life-cycle theory covers many different types of issues: 'social' issues (e.g. marriage and divorce), ethical issues (e.g. drug testing in animals), health issues (e.g. smoking, alcohol), consumer issues (e.g. product safety), environmental issues (e.g. pollutant emissions), labour issues (e.g. sweatshops), market issues (e.g. antitrust), among others. No issue is technological in itself; technology and innovation strategies are important types of substantive response to societal issues that *are framed as* needing a technological fix. Particularly, consumer issues (product-related) and environmental issues (product- and process-related) are prone to a technological frame (although, in theory, one could conceive technological fixes for any other type of issue as well). The model that I propose in the next Chapter will therefore account for the genesis process that *frames* problems as technological (or otherwise), in order to better understand the development of technologies and innovations in relation to societal problems.

To be sure, a few authors in the issue life-cycle tradition have touched upon 'technical' issues (but) without theorizing about their particular life-cycle. Post (1978) dedicated a chapter to 'The Promise of Technology', where he examined the case of fluorocarbons and the ozone layer. Although the author *did* look at the scientific research that lead to the understanding of the ozone layer depletion problem, his account takes the issue as a scientific (objective) fact and not as something socially constructed (i.e. Post did not look at the process of voicing a 'scientific trouble' as a public issue). Moreover, technology strategies were not conceptually embedded in his issue life-cycle model. From the second generation, Tombari (1984) listed a range of 'Strategic issues in the external environment' (chapter 4 in his textbook), amongst which figure 'technological innovation' as a particular type of 'issues to the public' (i.e. business externalities) that is closely linked to environmental issues, quality of life and the standard of living of a nation. However, Tombari did not delve deeply into what implications those kinds of issues have for an issue life-cycle. Also contributing to the second generation, Mahon and Waddock (1992) defined 'symbolic' and 'substantive' responses, without relating them to or looking at technological innovation. In the third generation, Mahon and McGowan (1996) defined technical issues and related them to the choice of responding to them alone or collectively – but the authors also did not look at innovation processes.

This lack of attention to technological development and the innovation process should <u>not</u> be regarded as a barrier for utilizing insights and concepts from this literature in my research. In fact, this presents an *opportunity* to enrich the literature with STI concepts, in a way that both addresses the gap in STI (identified in the Introduction chapter) and contributes to the development of the third generation of issue life-cycle theory: STI theory and issue life-cycle theory can fruitfully complement each other. To do so, I review next some useful concepts from STI studies. I will relate these concepts to the Triple Embeddedness Framework (see Introduction), which is the background framework that I use to integrate issue life-cycle theory with STI.

II.3.2. A Basic view of innovations and innovation management

Concepts from STI research field can fruitfully be used to enrich a model of issue life-cycle aimed at addressing the research questions of this thesis. A starting point is to look at how businesses manage innovation: firms in an industry deploy innovation strategies to create or secure competitive advantage (market shares, profitability) mainly in response or in anticipation to changes in the task (economic) environment (Tidd *et al.*, 2005). By innovating, a firm may convert environmental challenges into opportunities (Francis and Bessant, 2005). However, the innovation process is neither straightforward nor easy to accomplish, as it takes place under highly uncertain conditions (Tidd *et al.*, 2005; Lazonick and Mazzucato, 2013) related to what is technical feasible, economically profitable, socially acceptable or legally allowed (Tushman and Anderson, 1986; Nelson, 1994; Geels, 2002).

There are many ways to classify types of innovation (e.g. Abernathy and Clark, 1985; Freeman and Perez, 1988; Henderson and Clark, 1990; Francis and Bessant, 2005; for a review of product innovation typologies, see Garcia and Calantone, 2002). A common denominator of many of these typologies is the classification of the degree of novelty of innovations (Tidd *et al.*, 2005): innovations may range from being *incremental* to *radical*:

- 'Incremental innovation' are minor, continuous (Freeman and Perez, 1988), 'evolutionary' (Abernathy and Clark, 1985) improvements in existing products and processes. Incremental innovation is often the result of existing knowledge derived from experience (Tidd *et al.*, 2005) and thus draws on and reinforces the core elements of an industry regime (knowledge/capabilities and the technical regime, but also cognitive frames, beliefs, values etc., as they are all interdependent). *In my issue life-cycle* *model, I will portray incremental innovations as symbolic strategies in response to a societal issue.*

- 'Radical innovation' represents major, discontinuous events (Freeman and Perez, 1988), 'revolutionary' changes of products and/or processes that departs from and disrupts core elements of an industry regime. Radical innovation is often the result of active, deliberate research and development processes (Freeman and Perez, 1988; Tidd *et al.*, 2005). *In my issue life-cycle model, I will portray radical innovations as substantive strategies in response to a societal issue.*[23]

No matter the degree of novelty, developing innovations will always be uncertain (Lazonick and Mazzucato, 2013), because the probability of succeeding or failing cannot be calculated in advance. However, engaging in incremental innovation is a *less risky* enterprise than to engage in radical innovation, because development starts from something already known, whilst in the case of radical innovations, development involves the exploration of unknown areas (Tidd *et al.*, 2005). Incumbent firms in an industry will thus tend to favour an incremental technology and innovation strategy, sticking to technical products and processes they already know. Geels (2002, p. 50-1) lists the reasons behind this path dependence and inertia at the firm level, which I expand to lock-in mechanisms *at the industry level* by relating them to the industry regime:

- In an industry regime characterized by an overarching *mission* of profit maximization, sunk investments – associated with the established technology (e.g. assembly lines, process technologies, skills) – represent a key reason for why incumbents tend to resist engaging in disruptive/radical

[23] To be sure, incremental innovations may also contribute to demonstrating 'progress in resolving the actual problem', which is part of Mahon's and Waddock's (1992) definition of what substantive action is; while radical innovations may also be used to 'frame' the problem, which is part of these authors' definition of what symbolic action is (see quote on page 32). Key reasons for equating incremental innovations with symbolic action is that they *reinforce* the *status quo* (i.e. the technical element of an industry regime), are *less risky,* and require *fewer resources*, while radical innovations *disrupts* the regime, is *riskier* and require more resources. Another reason is methodological: equating incremental (radical) innovation with symbolic (substantive) action will allow me to operationalize and apply the model that I will develop in Chapter III to empirical cases, providing a concrete indicator for me to identify symbolic and substantive actions. Despite these rationales, I do recognize that equating incremental (radical) innovation with symbolic (substantive) action does not always hold in reality, and this is a caveat that I shall bear in mind in my case studies.

innovation that would ultimately destroy those sunk investments and damage profit margins (Geels, 2002).

- *Belief systems* lead to institutionalized search routines for technology development – the 'technological regime' (Nelson and Winter, 1982) – "which make engineers look in particular directions and not in others" (Geels, 2002, p. 50-1). Such cognitive frames may 'blind' actors to developments outside their core focus;
- A third reason is the industry-specific *technological regime* itself. "Organizations build capabilities around a particular trajectory [the industry technological regime] and those who may be strong in [...] an established trajectory often find it hard to move into the new one" (Tidd *et al.*, 2005, p. 25). In other words, as time goes by, industry-wide core technical competencies (Prahalad and Hamel, 1990) may turn into core rigidities (Leonard-Barton, 1992), limiting what firms can (and are willing to) do. Incumbents are thus less able to build up knowledge to cope with radical breakthroughs (or external shocks), and will tend to engage in competence enhancing, incremental innovations (Tushman and Anderson, 1986; Christensen, 1997; Geels, 2002) that exploit existing technological capabilities (March, 1991).
- A fourth reason relates to the incumbent industry orientation to markets, i.e. the aggregate economic positioning strategies of individual firms:

  ...firms tend to stay close to their main customers... Even if established firms notice newly emerging technologies, they may evaluate them negatively on a rational financial basis. First, disruptive technologies typically are first used in small and (relatively) insignificant market niches. The potential revenues from the discernible markets are small. [...] *Second, the firms' most profitable customers generally do not want, and initially cannot use, products based on disruptive technologies. The market signals from the main customers point to incremental rather than radical changes.* (Geels, 2002, p. 51)

- A final reason are industry specific *regulations* (and other policies such as taxes, subsidies, intellectual property laws, R&D programs, etc.), which influence markets and consumer choices, innovation processes, and business strategies (Geels, 2012a). Technologies and policy institutions co-evolve in a path dependent way (cf. David, 1994; Nelson, 1994), with

> regulations and other policies supporting certain established technologies and not others. Regulations therefore represent a form of 'lock in' (cf. Arthur, 1989; Unruh, 2000), which may ultimately prevent incumbent industry actors from developing radical new technologies.

An important corollary of these lock in mechanisms, which lead incumbents to follow an incremental path to technology development, is that more radical and disruptive innovations will tend to come from outsiders to the industry regime: (1) relative industry outsiders are not locked into the existing regime through sunk investments in core technologies; (2) outsiders have a different cognitive frame that allow them to look into different directions to develop technologies that appear radical relatively to the industry's technological regime; (3) outsiders may thus attempt to enter a new domain (secure a competitive advantage) precisely by developing radical innovations that destroy the competencies of the incumbent industry; (4) relatively insignificant market niches for more radical/disruptive technologies will be firstly seized by outsiders who do not have a vested interest in existing market linkages and customers (or, in other words, market niches represent an opportunity for outsiders to get a foothold in new domains); and (5) new regulations may provide a competitive edge to new entrant's products or processes. This is why radical, 'competence destroying' innovations are usually developed by firms new to an industry: "the source of the technology which destabilizes an industry [regime] often comes from outside that industry" (Tidd *et al.*, 2005, p. 24).

For an issue life-cycle model, those stylized facts imply that incumbents will firstly try to address the issue with minor changes in technology according to prevailing knowledge and capabilities (incremental innovation), while also employing resistant strategies to avoid higher-level changes in core beliefs and values. Given both the uncertainties involved in technology development and the regime's restrictive cognitive frame, incumbent firms will also find it hard to predict accurately development costs, time periods, markets and profits of new R&D projects that may be required in order to address the societal issue (Tidd *et al.*, 2005). Thus, if the societal issue calls for radical and disruptive innovations (and related changes in core regime elements), then it is likely that the issue will be initially perceived as a threat by incumbents, while outsiders may regard it as an opportunity to enter a new domain. If and whenever the societal issue translates into "new performance dimensions to be resolved by the engineers" (Abernathy and Utterback, 1978, p. 45), either via the emergence of new consumer preferences (new market niche) or initial (weak) regulations, then the first to (re)act will be relative outsiders to the industry regime, which develop new technological solutions.

When this happens, the costs of *not* mastering the new technological solution begins to rise to industry incumbents, so that they will attempt to defend their market domain, hedging against spillovers to mainstream markets and/or against stricter industry regulations. They will thus start to monitor outside developments and engage in knowledge building and exploration (March, 1991) of new technical solution via e.g. basic research, which may require the establishment of dedicated departments, if the field of knowledge falls outside the incumbent's (background or core) competency (Prencipe, 1997; *apud* Tidd *et al.*, 2005). If incumbents are not yet able to transform technical competence into profitable investment (Tidd *et al.*, 2005), when the new performance dimensions become mainstream, then cooperation with new entrants (Dyerson and Pilkington, 2005) is a possibility for technological catching up[24]. Meeting the mainstream demand will require large-scale financial commitments, so that competing firms have at this point an incentive to attempt to raise rivals' costs with e.g. exclusive patent rights or by lobbying policy-makers for enactment of regulations (Salop and Scheffman, 1983; Hackett, 1995; Puller, 2006 – see section II.3.3.2 for a review of the technology-forcing policy literature, which offer insights into the strategic use of technologies in response to regulation).

In summary, while the development of radical innovations by incumbents in response to societal issues is a risky and costly process, incumbents *can* reorient their strategies and contribute to addressing the issue. Reorientation of industry regimes is however a gradual long-term process that is likely to proceed through stages, just like an issue life-cycle, and, thus, both co-evolve. Changes in the regime are likely to begin with incremental adjustments in its technical element, but complete 'recreation' (Tushman and Romanelli, 1985), which entails changes in

[24] In fact, this may be a necessity, particularly in industries with complex product systems (like automobiles) that require a vast array of background technological competencies (Tidd *et al.*, 2005; Prencipe, 1997).

beliefs and mission, are likely to follow only if changes in regulation take place or if it makes economic sense (i.e. *mainstream* consumers demand the technical solution).

This first approach to how technology development and innovation strategies may impact on an issue life-cycle take the 'basic' Neo-Schumpeterian perspective of technological innovation as a basis for market competition (see e.g. Nelson and Winter, 1982; Fagerberg *et al.*, 2005): firms seek technological innovation to get strategic competitive advantage and secure 'monopoly rents'. While incumbents aim at raising barriers to entry by reinforcing their competencies, new entrants aim at changing the 'rules of the game' by engaging in innovation that will disrupt incumbents' competencies (Tidd *et al.*, 2005). If one follows this perspective, when technology is developed in response to a societal issue and brought to market, it is undoubtedly a kind of substantive response, i.e. a 'definitive move' (Mahon and Waddock, 1992) that demands the expenditure of significant amounts of resources (financial/productive/human capital etc.) and attempts to actually address the issue. In this view, technology and innovation strategies target *the economic task environment*. With the case studies, I aim however to investigate whether technologies strategies may also be aimed at the *institutional environment*. Some insights about this alternative use of technologies will therefore be incorporated in the model I will propose in the next chapter, so that I review these concepts in the next subsection.

II.3.3. Technological innovation and the institutional environment: the strategic use of technologies

II.3.3.1. The use of technologies as part of a legitimation process

Technology strategy can be used for socio-cultural (and politico-regulatory) reasons as well, that is, in response to pressures from the *institutional environment*. Technologies are devices that also "express overarching cultural values" (Hughes, 1995, p. 452), and thus a technology strategy can be deployed as part of a (re)legitimation process. To symbolically conform to pressures and expectations stemming from the institutional environment, "carefully chosen displays of symbolism may circumvent the need for substantive change entirely… Outputs [e.g. technologies], procedures, structures, and personnel can all signal that the organization labors on the side of the angels [i.e. those demanding changes to address a given societal issue] – even if these supposed indicators amount to little more than face work…" (Suchman, 1995, p. 588).[25]

One example of such strategic use of technologies is a prototype, which is "best described as […] tangible slices not only of technology and technique but of the corporation's own interpretation of market and cultural forces" and thus "says a lot about an organization, both internally to its workers, and to its customers [and other external stakeholders]" (Schrage, 1993, p. 56). For example, an environmentally-friendly prototype could be used as a much nuanced type of 'greenwashing' (Laufer, 2003; Delmas and Burbano, 2011) to signal to external stakeholders that the firm is committed to solving the issue and pre-empt governmental action (Maxwell *et al.*, 2000) – even if the firm has actually no interest in bringing the prototype to market. Another possibility is the use of prototypes to 'frame' (Mahon and Waddock, 1992) the issue, bringing legitimacy to a preferred technological solution (in detriment to alternative technologies). In both examples, technology strategies are deployed for symbolic reasons: they are either an attempt to cynically display 'social fitness' (DiMaggio and Powell, 1983; Oliver, 1991), build up goodwill and avoid more substantive actions or to make the issue frame congruent with core elements of the industry regime (values, interests, mission, beliefs, technical capabilities) of the organization deploying the strategy.

II.3.3.2. Technological innovation in response to regulatory pressures

The strategic use of technologies is also examined by the 'technology-forcing policy' (TFP) literature[26] (e.g. Miller, 1995; Kemp, 1997; Gerard and Lave, 2005; Puller, 2006; Gerard and Lave, 2007; Lee *et al.*, 2010; Tao *et al.*, 2010; Lee *et al.*, 2011), which looks at the interplay between the task environment and the institutional

[25] Suchman (1995) however cautions that such a symbolic strategy can have unintended consequences and may lead to cognitive dissonance at the industry level, gradually resulting in substantive responses.

[26] This is another literature related to the STI research field (besides the Greening of Industry literature, discussed in Chapter I) that can be said to have theorized about the development of technologies in response to societal issues, but with the restrictive focus on the 'implementation stage' of an issue life-cycle. Thus, in this literature it appears that technological solutions emerge only *after* a regulatory piece is approved, as if no technological development happened before – or influenced the content of – the policy. In other words, the literature overlooks how issues impact on technological developments, and how technologies may also shape policies (an understandable gap given its goal of examining how technologies and innovations may be 'forced' by policies). As Kemp (2005) noted: "problems [influence] political agendas that in turn influence technology solutions that influence perceptions" (p. 184). The model I develop in this thesis therefore attempts to account for this co-evolutionary dynamics.

environment. Besides leading to strategic games between firms in the regulated industry and regulators (Yao, 1988; Puller, 2006), technology-forcing policies may also trigger competitive struggles between business rivals in the task environment (Hackett, 1995; Puller, 2006; Gerard and Lave, 2007). The conceptualization of those dynamics provides important insights for a comprehensive model of issue life-cycle, so that I discuss them next.

Technology-forcing policies can be defined as "those that mandate firms to meet performance standards that go beyond the existing technical capabilities of the industry or to adopt specific technologies that have not been fully developed..." (Lee *et al.*, 2010, p. 249). Technology-forcing regulations therefore take different forms (Gerard and Lave, 2007): they may specify a *performance standard* or a *technology standard*. In the former case, the standard specifies a performance target (e.g. maximum CO_2 emission levels, minimum fuel economy levels) but does not mandate the use of any particular technology (i.e. any technology may be used to comply with the standard as long as it meets the performance criteria); in the latter case, regulation mandates the development and adoption of a specific technology that may exist but is not yet marketed. Moreover, the establishment of these standards may be *delegated to a regulatory agency* or *embedded in the law*[27] (Gerard and Lave, 2007): in the former case, the regulatory agency has the discretion to modify performance levels or to require different technologies, but when established by law, standards may only be modified by the legislative body (e.g. congress or parliament). No matter the particular shape a TFP takes, they represent an attempt by regulators to open up the 'regulatory lock-in' and promote the adoption of a technological solution that diverts from the incumbent technological regime.

Although some scholars question the effectiveness and economic efficiency (cost-benefit) of technology-forcing policies (see e.g. Jaffe *et al.*, 2003; Bansal and Gangopadhyay, 2005), the justification behind their adoption is the perceived lack of demand for technical attributes (or whole products) that address a societal problem, and thus the technology that would have those attributes (and/or meet performance criteria) are not supplied by the industry: "consumers might

[27] Note that, even if established by law, a regulatory agency is responsible for the enforcement and implementation of the standard.

systematically underestimate the effectiveness or value of these attributes [or products]... [...] The rationale for instituting a technology-forcing policy is that the preferred outcome of the government/regulator is a technological fix of the problem that can only be brought about by applying regulatory pressure on firms" (Gerard and Lave, 2007, p. 3). In other words, regulations are enacted as a substitute for effective consumer demand that could induce R&D investments for the development of technological solutions to societal issues.

However, the link between technology-forcing regulation, increased R&D investments and technological innovation is not clear-cut: "The implementation phase of the technology-forcing process is murkier than the theory suggests" (Gerard and Lave, 2005, p. 765). Countervailing forces mediate this relationship and lead to dynamic games between competing firms in an industry, between these and outside firms, and between the whole industry and the regulatory body:

1) Regulated <u>incumbent firms</u> have an incentive to *increase R&D investments* and innovate in order to *reduce compliance costs*: The cost of R&D is in itself a disincentive to innovate[28], so that "[f]irms will have lower costs if regulations are not enforced... Therefore, it might be in the interest of the firm (or the industry collectively) to lobby the regulators to delay or rescind the standard" (Gerard and Lave, 2005, p. 764). This could be expected in the early stages of an issue life-cycle. However, if regulation cannot be prevented, then to invest in R&D in anticipation of a TFP may speed up a firm's learning process and cut the financial and technical uncertainties surrounding the technological innovation development, ultimately reducing compliance costs (Lee *et al.*, 2010). One could expect (some) incumbents to start hedging against 'undesirable' policy outcomes during the policy-making process and to accelerate the development of more radical technologies during implementation stage.
2) For <u>incumbent firms</u> (in particular), the *risk of liability claims* represent a *disincentive to invest in R&D* and innovate: given the uncertainties concerning reliability, effectiveness and unintended consequences of adopting a new technology, the risk of facing liability claims in case of technological failures

[28]The possibility that knowledge and technological breakthroughs may spillover to competitors ('free-riders') that did not invest in R&D is another disincentive to innovate (Gerard and Lave, 2007).

provide a disincentive for firms to innovate (Gerard and Lave, 2007). Firms in a regulated industry may thus decide to take legal action and contest the TFP in court if they believe that no technology can meet the regulation or that the policy requires an unproven and risky technology. Such strategy can be expected during the implementation stage of an issue life-cycle.

3) The possibility of *entering a new domain* provides an incentive for relative industry regime outsiders to *increase R&D investments* and innovate: the TFP provides an entry point for relative industry outsiders, such as suppliers and foreign competitors (Gerard and Lave, 2007; Lee *et al.*, 2010) that may want to diversify their market domain. Even before a technology-forcing policy is enacted, one could expect those outside actors to already increase R&D efforts (Lee *et al.*, 2010) to demonstrate technological viability and thus influence the policy-making process. Thus, strategic action by relative regime outsiders can be expected to take place early on in the policy-making stage of an issue life-cycle. However, because "[n]ew ideas are more likely to succeed with the support and leadership of one or more of the major players" (Dyerson and Pilkington, 2005, p. 406), later in the TFP implementation process those new entrants have an incentive to seek partnership with incumbents. Equally, incumbents may be willing to establish such a partnership with new entrants if they anticipate synergic benefits for themselves. Cooperation is therefore expected as the implementation process advances.

4) The possibility of *raising rivals' costs* represents an incentive for individual incumbent firms to *increase R&D investments* and innovate: an individual firm may innovate and ultimately encourage regulation if it believes to have a technical and cost advantage over competitors in complying with the TFP. "[I]ncumbent firms can benefit from [...] regulations that prevent entry or [that raise] some firms' costs more than others" (Puller, 2006, p. 692). Thus, regulated firms are not simply 'regulation-takers': by complying with a TFP an individual firm may be able to influence its content (Gerard and Lave, 2007), especially when the detailed content of the TFP has not been established by law and is delegated to a regulatory agency. Such incumbent strategy seeks to secure a first-mover advantage over its rivals, by e.g. transforming a technology (over which the firm has a competitive advantage) into a *de facto* standard.

Raising rivals' costs, influencing the implementation process and securing a first-mover advantage can be expected in the issue life-cycle implementation stage.

5) Finally, the possibility of *pre-empting the regulation* (or '*ratcheting the regulators credibility*') provides an incentive for all incumbent firms in an industry not to invest in R&D and innovate: for the TFP to be effective, sanctions must exist in case of non-compliance and, more importantly, regulated firms must believe that these will be enforced (Lee *et al.*, 2010; Gerard and Lave, 2007). But even if the incumbent industry believes that the policy *will* be enforced, it may have an incentive not to develop a technology and claim it is not feasible to meet the regulation, in order to defend sunk investments and complementary assets: the development of a technology is not a deterministic process, and it may happen that no technological solution is established even if the industry invests in R&D. Therefore, TFPs usually include a clause that pre-empts the legislation in case no technological breakthrough is reached even after 'good-faith' efforts to establish it. The industry may *strategically withhold investments in R&D* to 'ratchet regulation' (Puller, 2006) and force a review of the technology-forcing policy. It is up to the regulatory agency (or to legislators) to determine whether a good-faith effort was made or not. The implementation of a TFP is thus complicated because of information asymmetries between firms and regulators concerning technological developments:

> *When an information asymmetry exists, firms can attempt to force a regulatory delay by deliberately missing the standard... Active collusion is not necessary to achieve this result. For example, a firm that believes no other firm (or potential entrant) can meet the standards will autonomously reduce its R&D effort. If each firm has such an expectation, then the expectations will be self-fulfilling.* (Gerard and Lave, 2005, p. 764)

To assess whether performance or technological standards are feasible, the regulatory agency may invest in building up sufficient in-house technical expertise to diminish information asymmetries (Lee *et al.*, 2010), or it may rely on external sources of information (Gerard and Lave, 2007): industry outsiders and individual firms seeking to raise costs for competitors have an incentive to share information with the regulator to guarantee that the TFP will be effectively implemented, so that the raising rivals' costs effect and the ratcheting credibility effect interact (Puller, 2006). During the implementation stage, there is therefore a contradictory dynamics between *raising rivals' costs* (acting alone) and (collectively) *pre-empting the regulation*.

For a comprehensive model of issue life-cycle, those aspects imply that: (a) incumbent firms in an industry will first lobby against a TFP, given their resistance to engage in radical innovation and the possibility that the technology required by the policy will destroy their competencies; (b) industry regime outsiders will attempt to seize the opportunity that a TFP creates (establishment of a new market domain), and thus try to influence the regulatory process by lobbying and collaborating with policy-makers and regulators in favour of the TFP; (c) if the TFP is enacted, incumbent firms may seek legal action to contest the legislation in court, given the risk of liability claims; (d) if the judicial avenue fails, incumbents will have to catch up with technological developments by outside firms and thus may aim to delay implementation of the TFP or to pre-empt it altogether by withholding information from regulators; (e) at some point in the implementation process, individual incumbents (or coalition of incumbents or incumbent-outsider partnerships) may attempt to depart from the industry regime and develop a more radical technological solution of their own to raise rivals costs or to block the entry of regime outsiders, thus speeding up the adoption of the innovation. These stylized facts are to be incorporated in the issue life-cycle model that I will develop in the next Chapter, and will be empirically investigated in the case studies.

II.4. The dynamics of attention: issue-attention cycles and technology hype-cycles

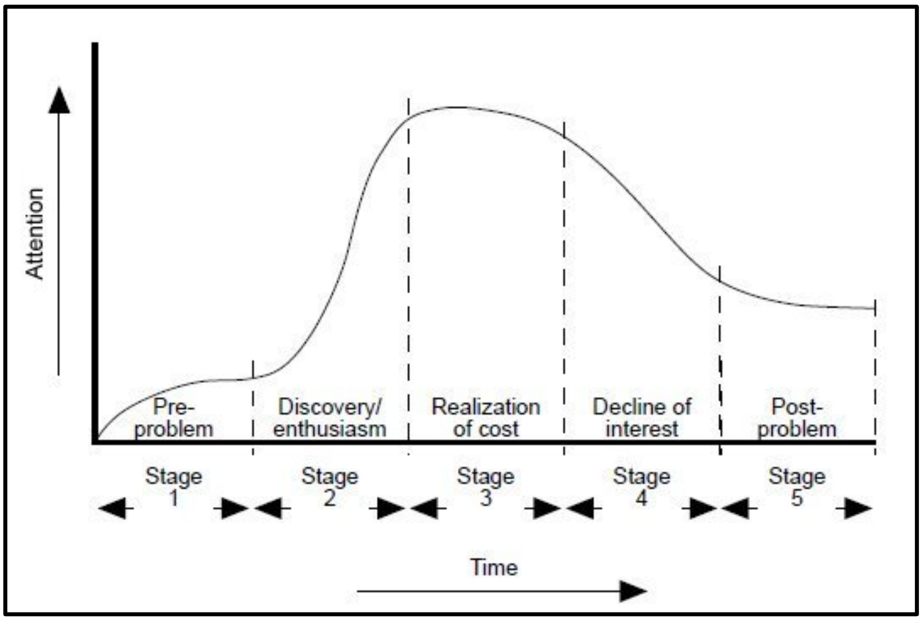
II.4.1. Issue-attention cycles

Since the second generation of issue life-cycle theory, the dynamics of attention devoted to an issue has been used to graphically depict an issue life-cycle: public attention was suggested (Wartick and Mahon, 1994) as a surrogate measure for 'intensity of concern' (Tombari, 1984) with an issue. For some authors (Graves *et al.*, 2001; Wartick and Heugens, 2003; Zyglidopoulos, 2003), the so-called 'issue-attention cycle' (Downs, 1972) is the *same* as an issue life-cycle. This supposed identity is however unwarranted, and stems from an unsystematic integration of both concepts. Issue-attention cycle theory in fact offers a possible explanation for the dynamics of public and political agenda-setting (Howlett, 1997) and should be considered as such. Here I highlight some aspects (and caveats) of the issue-attention cycle theory.

Proposed by Downs (1972), the concept of an issue-attention cycle suggests that public attention towards a problematic condition (issue) would follow discernible – "almost predictable" (Newig, 2004, p. 150) – patterns through time, rising and falling *independently* of material aspects and objective developments of the condition itself. The underlying idea is that public attention is a scarce resource (Newig, 2004), which has to be allocated to competing issues. When the complexity of addressing a given issue is realized by public opinion, attention devoted to it would inevitably decline (Downs, 1972).

Based on this intuition, Downs (1972) proposed a five-stage model of issue-attention cycle (Figure II.6): (1) the 'pre-problem' stage, when only experts or a minority perceives a given condition as problematic (low attention level); (2) the 'discovery and enthusiasm' stage (increasing attention), when the public suddenly 'discovers' the issue (normally in reaction to a dramatic and/or evident event), becoming enthusiastic with possible fixes; (3) the 'realizing the cost of the solution' stage, which normally would occur at the peak of the attention cycle, substituting the previous enthusiasm; (4) the 'gradual decline of interest' stage, when attention shifts towards other issues, because the public becomes discouraged and/or 'bored' with the issue; and (5) the 'post-problem' stage, when the issue further fades away. Yet, after the completion of such cycle, and despite the decline in public attention, Downs suggest that the issue might be easily reactivated, due to the public's familiarity with it and to the institutions created along the process. Assuming that the government would react to increased public attention to an issue, one implication of the Downsian issue-attention cycle is that "public interest in a particular issue would peak [third stage] and be followed by governmental attention. Public interest would then tend to fall off, as would government activity" (Howlett, 1997, p. 10). Another implication is that public attention has to be constantly drawn to a given issue by e.g. activists or the media (in Lamertz *et al.*, 2003, this activity is labelled 'attention advocacy').

Figure II.6: The Downsian issue-attention cycle

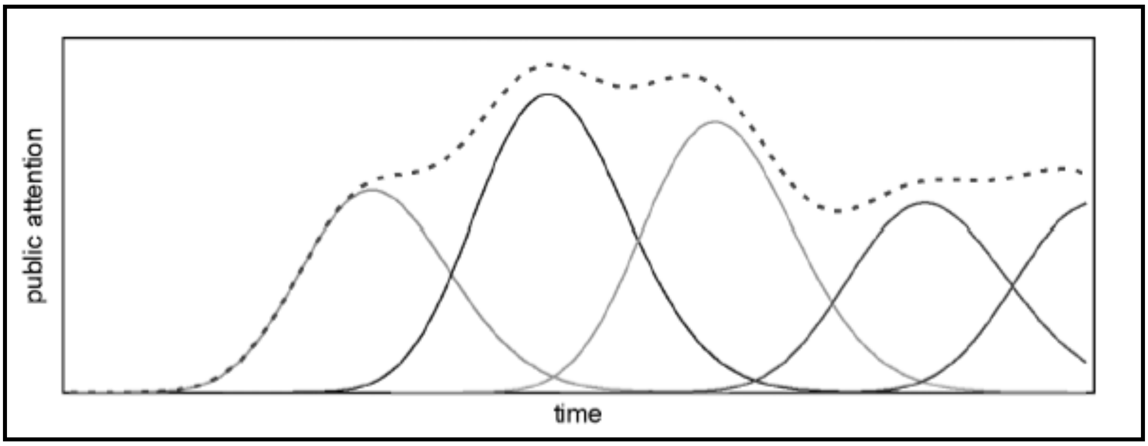


Source: Adapted from Kirkwood (1994)

Downs' theory was subsequently tested by many authors, not just for issues faced by the American public (e.g. Peters and Hogwood, 1985; Neuman, 1990), but also in other countries such as Canada (Howlett, 1997) or Germany (Newig, 2004). Empirical validity of the Downsian issue-attention cycle and the 'spillover effect' (the issue moving from public to governmental agenda) has been considered 'weak at best' by some authors (Howlett, 1997; Peters and Hogwood, 1985), but others claim that empirical tests had been affected by problems with the quantitative methodology applied (Henry and Gordon, 2001) or with the definition of key concepts (Newig, 2004), e.g. mixing public attention with public opinion (while attention is a scarce resource and volatile, opinion is not scarce and presents more temporal stability). These more recent studies (Henry and Gordon, 2001; Newig, 2004), using sophisticated statistical methods, did find evidence of attention cycles and spillover effects.

Newig (2004) also suggested that problems with identifying an attention-cycle could be related with the level of aggregation: large-scale problems such as 'the environment' would "serve as categories comprising and thereby classifying the multitude of different [smaller-scale] issues" (p. 155), such as local air pollution (smog), deforestation or ozone depletion. Attention to those broad categories would not present the cyclical pattern implied by Downs' theory, because the dynamics of public attention towards a broad problem area would be composed by the sum of attention-cycles of single, small-scale issues (Figure II.7).

Figure II.7: Public attention to broad problems as the sum of single issue-attention cycles



Source: Figure 2 in Newig (2004, p. 156)

Issue-attention cycle theory has however been criticized conceptually. Three key issues have been raised regarding this theory: (1) Lack of agency – issue-attention cycle theory tends to ignore that issues are socially constructed, downplaying interpretive disagreements about the definition of 'problematic' conditions (Hilgartner and Bosk, 1988); (2) Spillover mechanisms are underspecified – in Downs' (1972) original formulation, it is not clear which are the mechanisms that makes an issue spillover from the public agenda to the political agenda, nor whether there is a two-way causality between public and political agendas (Liu *et al.*, 2011). This second issue is also reflected in (3) the choice of media attention (e.g. number of newspaper articles on a particular issue) as a proxy variable for public attention, which raises the question about whether media follows or leads the public.

Because of these conceptual caveats, issue-attention theory should be incorporated with caution into my issue life-cycle mode. Criticism one can be addressed by considering the work by Lamertz *et al.* (2003, reviewed in section II.2.3), who incorporated social constructivist theory into their issue life-cycle model. In fact, the model I will propose draws on dialectical logics, in which the issue life-cycle advances through struggles between antagonistic actors (those pushing the issue onto the agenda and exerting pressure on the incumbent industry, and incumbent industry actors). Public attention is galvanized not because of 'dramatic events' *per se*, but through purposive action of activists (e.g.

the 'minority' or 'experts' from the first stage in Downs' model) who purposively draw attention to those events and voice them as problematic and dramatic (cf. the discussion of Kingdon's model above). Attention does not drive an issue life-cycle: the perspective I take is that issue-attention cycles *reflect* issue life-cycle dynamics; I propose that *attention indicators* can fruitfully be used as part of a methodology that links issue life-cycles and empirical case studies. One solution to problems two and three is to consider – as demonstrated by different authors – that media, public and political attention (amongst other types of attention indicators) co-evolve and reinforce each other (Liu *et al.*, 2011; Newig, 2004) and that spillovers from one arena to another requires the achievement of certain attention thresholds (Neuman, 1990). These attention thresholds therefore serve as indicators for phase shift in historical case studies.

Thus, my model will consider the following qualitative insights offered by issue-attention theory:

- Attention devoted to an issue by different actors – e.g. the public, the news media, politicians and policy-makers, also experts (Molitor, 1977) and the industry (Hoffman and Ocasio, 2001) – fluctuate and co-evolve overtime (Downs, 1972);
- Events are purposively constructed as dramatic to attract attention to what is perceived as a problematic condition (Hilgartner and Bosk, 1988; Lamertz *et al.*, 2003);
- Different issues compete for attention from the different actors (Hilgartner and Bosk, 1988; Hoffman and Ocasio, 2001);
- Attention devoted to an issue by actors in one arena co-evolves with the attention in other arenas (Hilgartner and Bosk, 1988; Newig, 2004; Liu *et al.*, 2011);
- Key spillover mechanisms are media attention to an issue and the work of activists, both of which draw attention to the issue (Lamertz *et al.*, 2003, Rivoli and Waddock, 2011);
- An issue may also spillover from arena A to arena B when attention is high in arena A (Neuman, 1990);
- Action in response to an issue is more likely at certain times when many different actors converge their attention towards the issue (Molitor, 1977);

- An issue that has attracted attention in the past may attract attention more easily than a new issue (Downs, 1972).

Some of these qualitative insights will be explored also through quantitative methods (see Chapter IV); for instance, I will try to explore the notion that 'attention devoted to an issue by actors in one arena co-evolves with the attention in other arenas' with the aid of statistical methods (meta-correlation analysis). Furthermore, the idea that issue attention cycles reflect qualitative developments of an issue life-cycles provides a clue as to how to objectively delineate the different life-cycle stages, something that I also aim to explore with the mixed-methods methodology (and, in particular, the use of statistical tests for unknown structural breaks – see section IV.2.2.3).

II.4.2. Technology hype-cycles

A second type of attention dynamics is associated with new technologies. So-called 'technology hypes' "are characterised by an upsurge of public attention and high rising expectations about the potential of the innovation. Hypes are, per definition, followed by a considerable decline of attention that may go hand in hand with a disappointment of the hyped expectations" (Ruef and Markard, 2010, p. 317).

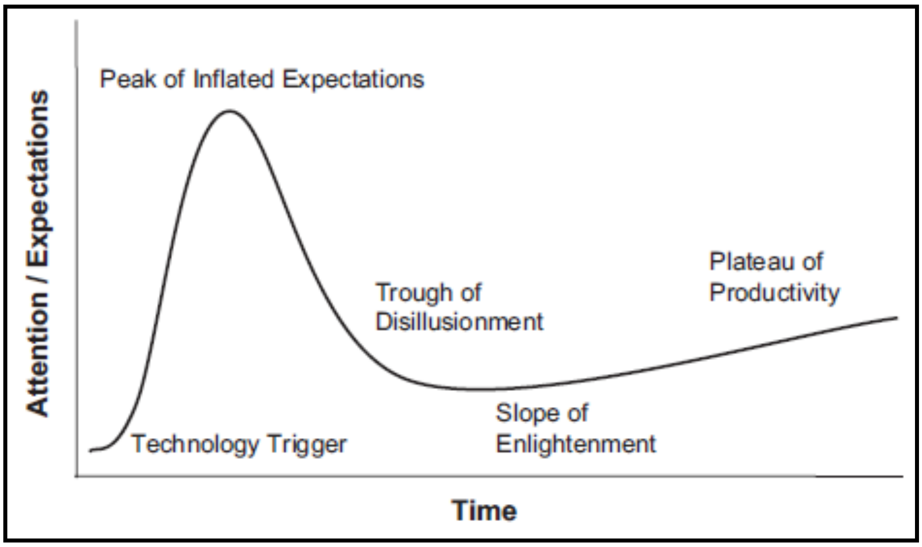
In common parlance, 'hype' has a negative connotation, implying unrealistic expectation regarding the technology that went through a hype-disappointment cycle (Bakker, 2010). However, some scholars have argued that upsurge of expectations fulfils a performative role (van Lente, 1993), as it leads to cultural enthusiasm that helps foster public acceptance ('societal embedding') of the new technology (Geels *et al.*, 2007); triggers institutionalization processes that help legitimize technologies (Ruef and Markard, 2010) and thus breaks up with the 'liability of newness' syndrome[29] (Stinchcombe, 1965); attracts sponsors – such as venture capitalists (Geels and Smit, 2000) – that promote a fast development of the technology (Bakker, 2010); and act as a coordinating device (Ruef and Markard, 2010). However, after the hype, when the technology goes through a phase of disillusionment, resource mobilization may become more difficult, sponsors and other actors may withdraw from development activities, and the reputation of the

[29] The 'liability of newness' is a phenomenon according to which entities (organizations, technologies etc.) have higher probability to die in the earlier stages of their existence, due to distrust from other actors and other factors such as economic inefficiencies (slow learning curves).

technology may crucially be impaired before consumers, policy-makers and other stakeholders (Bakker, 2010; Ruef and Markard, 2010).

Technology hype-cycles has also been used as a market research tools by *Gartner Consulting Group*, which developed a 'technology hype-cycle research methodology' (Gartner Research, 2013). Many academic studies (Geels *et al.*, 2007; Bakker, 2010; Ruef and Markard, 2010) have drawn on the five-phase Gartner Technology Hype-cycle (Figure II.8), which bears some resemblance to the Downsian attention cycle (cf. Figure II.6). The cycle begins with (1) a 'technology trigger', an event (e.g. technology breakthrough, scientific discoveries) that lead to a surge in (e.g. media, public, political, industry) interest and attention; (2) this surge in interest is accompanied by growing positive expectations about the technologies, which results in a hype ('peak of inflated expectations'); however, as the technological developments fail to meet the inflated expectations, the technology (3) passes through a 'through of disillusionment', which may even lead to its 'shelving' (Geels *et al.*, 2007); despite the disillusionment of the majority, some continue to work on the technology, leading to (4) greater understanding of barriers and potentials of the technology ('slope of enlightenment') and (5) gradual productivity increases ('productivity plateau', which is accompanied by lower expectations and a relatively stable devotion of attention). During the fifth stage, "the technology might make its way to the market after all" (Bakker, 2010).

Figure II.8: The Gartner hype-cycle



Source: Figure 1 in Bakker (2010, p. 6541)

This discussion reveals a very important point about issue life-cycles: they are accompanied by *cycles of attention to the issue itself* (and the different ways it is framed) and *cycles of attention to the solution* (such as a technology). When the issue is framed as technical, the cycles of attention to the solution takes the shape of a *technology hype-cycle*. While the qualitative insights from issue-attention theory (which I have pointed out in Section II.4.1) can be theoretically incorporated in an issue life-cycle model, the question of how an issue life-cycle is affected by technology hype-cycles remains open. Another open question is: how do issue-attention cycles and technology hype-cycles co-evolve? Rather than trying to *a priori* incorporate technology hype-cycle theory in my model, the strategy I will adopt is to investigate these questions empirically through case study. Therefore, part of the selection criteria for at least one of the cases should be the existence of identifiable technology hype-cycle(s) throughout the issue life-cycle. I will address these questions by employing a 'mixed methods' analytical approach (see Chapter IV): issue-attention cycle and technology hype-cycle theory allows for a *quantitative* assessment of issue life-cycles, which complements the proposed *qualitative* model of issue life-cycles.

II.5. ORGANIZATIONAL INSTITUTIONALISM: CORPORATE POLITICAL ACTIVITIES, SOCIAL LEGITIMIZING STRATEGIC ALLIANCES AND REASONS FOR ESTABLISHING VOLUNTARY INTERORGANIZATIONAL RELATIONSHIPS

The review of issue life-cycle literature revealed attempts to link political strategies by incumbent industries to phases of the issue-life cycle. The most developed view of political strategies throughout an issue life-cycle has been developed by Bigelow *et al.* (1991) who argued that political strategies move sequentially from 'containment', to 'control', to 'bridging' and to 'influence'. While this represented an important advance in early issue life-cycle theory, the third generation did not move this conceptualization further. However, the flourishing literature on Corporate Political Activities (CPA) (Oliver, 1991; Schaffer, 1995; Hillman and Hitt, 1999; Ansolabehere *et al.*, 2002; Schuler *et al.*, 2002; Hillman *et al.*, 2004; Oliver and Holzinger, 2008) offers an opportunity to further systematize corporate political activities throughout an issue life-cycle.

II.5.1. Corporate Political Activities: political strategies and tactics in response to a societal issue

A good starting point is the model of corporate political activity formulation developed by Hillman and Hitt (1999). They argue that "firms that have decided to be politically active face three sequential decisions: (1) approach to political strategy, (2) participation level, and (3) specific strategy choices" (p. 825). The first decision depends on whether CPA focus on a single, focal issue (a 'transactional approach') or on a continuous relationship with e.g. congressmen (a 'relational approach'). Given my interest in issue life-cycles, I will consider this decision as a given: firms-in-industries will chose a 'transactional' approach to CPA.

The second decision concerns the choice of engaging in political action *individually* (i.e. the firm acts alone to affect public policy) or *collectively* (through collaboration of cooperation between one or more firms). This is a rather important choice, which I will look in more detail below.

The third decision concerns the choice of general strategies and specific tactics. Drawing on the works of Hillman and Hitt (1999), Schuler (2002) and Oliver and Holzinger (2008), plus the political strategies discussed in the issue life-cycle literature, I distinguish five types of political strategies and associated tactics (Geels and Penna, 2013):

a) *Constituency-building strategies*, covering grassroots mobilization (of employees, suppliers, customers etc.), advocacy advertising, public relations, press conferences, political education programmes etc. These strategies aim at forming a coalition around a favourable issue-framing (which may include or take the form of denying the issue).
b) *Public information strategies*, which comprises tactics such as commissioning research projects or setting up research institutes to investigate the problem and reporting results, testifying as expert witnesses to frame the problem in favourable ways in official political forum (e.g. policy hearings in congress), supplying technical reports etc. This strategies also aims at framing the issue, but focus on technicalities of the issue (i.e. it involves the recognition of an issue as such) and aims at influence 'official' framings;
c) *Direct lobbying strategies*, e.g. hiring lobbyists; mobilizing CEOs to speak with politicians. This is a kind of information strategy (Hillmann and Hitt, 1999),

however, the content of the information is less technical, and it often happens behind closed doors, e.g. 'green room meetings'[30]. Therefore, I separate lobbying from other information strategies.

d) *Financial incentives strategies*, covering tactics such as contributions to politicians or parties (e.g. Political Action Committees/PAC contributions, in the US), paying honoraria for politicians/policy-makers (e.g. for their speech in events), hiring politicians who formerly occupied public positions etc.

e) *Confrontational strategies*, e.g. opposing laws through litigation; 'blackmailing' (e.g. threatening policy-makers with plant closures, layoffs, or relocation); non-compliance (e.g. drawing on economic power) to create stalemates.

While nothing prevents firms and industries to engage in all kinds of political strategies during all phases of an issue life-cycle, I propose that:

- Constituency building strategies are more likely in early stages of an issue life-cycle, when the issue framing is still ill-defined. These strategies seek to counter claims by activists and organized social movements. Indeed, the creation of an organized social movement is an important event in an issue life-cycle, for they mobilize resources (finance, personnel etc.) and draw attention to problematic conditions (through demonstrations, campaigns, boycotts, petitions etc.), with the aim of creating drama and a shared sense of urgency. Social movements thus are also active in framing and political strategies, thus giving rise to framing and political struggles with firms and industry associations.
- Information, direct lobbying and financial incentives strategies are likely when the issue starts to spill over to the political arena and begin to influence 'macro-politics', i.e. the workings of Parliament, Congress, and the executive government (True *et al.*, 1999). If this leads to hearings and investigations, which usually accompany policy-making processes, the release of technical information becomes a key political strategy to prevent or influence the content of regulations.

[30] The term 'green room' originates in British theatre and refers to the waiting room where performers would wait until their time to go on stage. The expression became jargon in international trade negotiations, referring to an informal, restrictive process to settle 'sensitive issues' by consensus amongst a limited number of delegations (see http://www.wto.org/english/tratop_e/dda_e/meet08_org_e.htm#green_room, accessed on July 26th, 2013). Its use has now spread to mean political negotiation processes behind closed-doors.

- Finally, confrontational strategies are likely to be employed during the implementation process of regulation. Moreover, firms and industry associations may continue with information strategies, now targeting regulators (e.g. in regulatory agencies), drawing on legal ambiguities and loopholes. This may lead to delays, gridlocks and stalemates in the issue life-cycle.

These strategies and tactics are not mutually exclusive, but rather part of a portfolio of options that may be deployed in combination, too. Moreover, they may be deployed individually or collectively, so an important question is whether and when firms will form alliances and act through industry associations and other types of coalitions.

II.5.2. Social legitimizing strategic alliances and reasons for establishing voluntary interorganizational relationships

Although some authors that proposed issue life-cycle models (e.g. Mahon and McGowan, 1996; Rivoli and Waddock, 2011) recognized that the corporate decision to respond to societal issues alone or collectively is important for the issue's evolutionary dynamics, none has systematically incorporated this factor in their models. Following the suggestion by Näsi *et al.* (1997) and Wartick and Heugens (2003) that issue life-cycle theory could be fruitfully enriched with insights from Institutional Theory, I here review specific studies from Organizational Institutionalism that have theorized about interorganizational relationships/strategic alliances, in order to incorporate this dynamic interplay in my novel model.

Dacin *et al.* (2007) proposed that firms may enter into a strategic alliance to gain different types of *legitimacy*. For an issue life-cycle model, it is interesting to look at the factors affecting the establishment of an interorganizational relationship (IOR) for *conformity with societal rules and expectations* (i.e. for *social* legitimacy):

> *A firm will be more likely to enter a strategic alliance to gain social legitimacy when it (a) is closely monitored by institutional constituents, (b) depends on a socially responsible image for success, (c) engages in activities or produces outputs that are highly visible and controversial, and (d) lacks a socially responsible image.* (Dacin *et al.*: 2007: 177)

All this factors are affected by the life-cycle of an issue that concerns an industry. I take however point (d) as a starting point: as other authors suggested (see below), when industry members perceive that their collective 'responsible image' (or, better, responsible 'reputation') is being questioned, they may decide to engage with the issue collectively. Thus, the relevant question is: in an issue life-cycle, when does the industry's responsible reputation begin to be damaged?

Hoffman and Ocasio (2001) suggested that collective industry attention to a given issue depends on whether the industry is publicly held accountable for it: industry members "are concerned about whether others hold them accountable for specific actions or events [issues]" (Hoffman and Ocasio, 2001, p. 422), because such accountability poses a threat to their 'shared identity' (a core element of an industry regime). Accountability for an issue affects the industry's reputation and may ultimately put into question individual firms' 'license to operate' (goodwill/social legitimacy). The industry may feel a threat to their 'identity' depending on the issue *frame* (Lamertz *et al.*, 2003). "The ideal-typical social problem claim [framing] asserts that a problem exists and is important, includes ideas of causal responsibility and normative (political or moral) responsibility [accountability], and proposes solutions to address the problem or redress the harm" (Hilgartner and Bosk, 1988, p. 62, ft. 10).

Therefore, whether a societal issue will trigger collective action depends on the issue's underlying frame. I argue that the threat to the shared identity may be posed directly or indirectly, depending on which regime element (see Figure I.1) is questioned. The direct threat happens when the industry's *mission and behavioural norms* or *informal internal regulations* are put into question. The indirect threat happens when their *belief systems* or *technical regime* is questioned. Logically, because regime elements are interrelated, questioning one element may raise questions about other element(s), e.g. often, the industry's mission encompasses production and sale of a particular technology, so that questioning the mission is questioning the technical regime and vice-versa.

This thesis is particularly concerned with threats to industry's identity due to issue framings that relate to *technical regimes*. So, to be more specific, I argue that when the issue is framed as technological and affects the distinctive competency of the *entire* industry, it becomes an institutional issue demanding an industry-wide response, because it poses an indirect threat to the industry's identity – shared interests of all firms-in-industry are then at stake (Geels and Penna, 2013). Thus, after the issue receives such negative (to the industry) framing, individual firms are likely either to establish a new *industry-wide* 'interorganizational relationship' (IOR) or to make use of existing (industry-wide) trade associations to contest the threatening issue frame (leading to a framing struggle). These 'closed industry fronts' or 'political coalitions' work as coordinating devices to defend the *status quo* during the issue life-cycle.

Oliver (1990) identified five reasons ('critical contingencies' or causes) for establishing voluntary interorganizational relationships (a sixth contingency, 'necessity', leads to an IOR mandated by law, i.e. not voluntary): (1) Asymmetry; (2) Reciprocity; (3) Efficiency; (4) Stability; and (5) Legitimacy:

1) *Asymmetry*: when the IOR is established to exert power over a third party. This IOR is triggered when the organizational partners are threatened with "the loss of decision-making latitude and discretion" (Oliver, 1990, p. 244);
2) *Reciprocity*, when an IOR is established because it promotes mutual benefits for the partners. This contingency emphasizes collaboration, cooperation and coordination between organizations. Note that an asymmetric IOR may be disguised as reciprocal to avoid indictments of collusion (Oliver, 1990, p. 254).
3) *Efficiency*, when the IOR aims at obtaining an economic advantage through lowering transaction costs.
4) *Stability or predictability*, when the IOR is an adaptive response to environmental uncertainty. The IOR serves "as coping strategies to forestall, forecast, or absorb uncertainty in order to achieve an orderly, reliable pattern of resource flows and exchanges" (Oliver, 1990, p. 246);
5) *Legitimacy*, when the IOR is established "to demonstrate or improve [members'] reputation, image, prestige, or congruence with prevailing norms in its institutional environment" (Oliver, 1990, p. 246), e.g. by publicizing social responsibility. "Most associations attempt to increase members' legitimacy, and public relations campaigns to enhance the image of the trade are commonly a central responsibility of associations. However, associations are more likely to

form for legitimacy reasons in response to explicit institutional and public criticism" (Oliver, 1990, p. 252).

Initially (i.e. after the issue is framed), firms are likely to establish an IOR for reasons of legitimacy. But IORs may be established or maintained for other reasons as well. For instance, when there is threat of governmental intervention in an industry (an asymmetrical relation), the industry can make use of a trade association to lobby against regulation (preempt regulatory action) and promote the interests of its members. The association is also important to coordinate individual members' actions (reciprocity) and avoid duplication of efforts (efficiency). The IOR may also reduce legislative uncertainty through the dissemination of information about political developments to its members, or it may promote voluntary standards and guidelines (e.g. for products) to forestall the unpredictability of governmental regulation (Oliver, 1990) – in both cases, the IOR is used to keep stability and predictability.

Oliver's analysis thus offers insights into the *duration* of a strategic alliance in an issue life-cycle. When an individual member perceives that the cost of maintaining an IOR does not translate into increased benefits for itself (i.e. the IOR is not perceived as reciprocal anymore or is perceived as inefficient) or when the member anticipates strategic economic advantages (i.e. more efficiency and legitimacy) by acting alone, then it may decide to depart from the alliance. Furthermore, as we saw in the review of the technology-forcing policy literature, a technology-forcing regulation provides contradictory incentives for firms in an industry: on the one hand, firms have an incentive to *collectively* avoid innovation to ratchet the regulator's credibility; on the other hand, individual firms have an incentive to innovate *alone* to raise rivals costs (or decrease its own costs). Thus, it seems plausible that an *industry-wide* IOR will be dissolved at some point in the implementation stage of an issue life-cycle, particularly when uncertainties concerning the actual contents of the technology-forcing regulation are reduced (i.e. individual firms do not need an IOR to maintain stability anymore).[31]

[31] However, as discussed in the section above on innovation management, the establishment of a more 'restricted' IOR between an individual incumbent firm and a new entrant that holds important background competencies is also a possibility later in the implementation stage.

II.6. CONCLUDING REMARKS

The aim of this chapter was to look for relevant insights, which I could use to address the puzzle of understanding how, when, and why incumbent actors change their technological strategy to address a societal problem. The next Chapter will provide a conceptual answer to these questions, by using the relevant insights as building blocks of a comprehensive model of the issue life-cycle that captures pressures, responses and technological developments and will thus allow addressing my research questions.

III. CONCEPTUAL FRAMEWORK: THE DIALECTIC ISSUE LIFE-CYCLE MODEL

III.1. INTRODUCTION

This Chapter integrates the insights (or building blocks) raised in Chapter II into a coherent conceptual framework (or heuristic model), which will allow me to address the main research questions in this thesis: How do societal issue-related pressures (on industries), from different domains (e.g. civil society, science, political arena, economy), evolve? How do industries respond to changing pressures around societal issues, in terms of technological, political, cultural and economic strategies? In particular, when and why do industry actors decide to develop substantial technological responses?

To integrate those insights, I will build on the field-level 'Triple Embeddedness Framework' (see section I.3). This synthetic framework of industry dynamics has three characteristics that facilitate the integration of the building blocks into a coherent whole for explaining the research questions: (a) it posits interactions between industry and environment, which will allow me to conceptualize how the industry regime co-evolve over time with pressures related to societal problems; (b) it shows that industry strategies in response to environmental pressures are multi-dimensional; and (c) it provides a frame of reference, based on the core elements of industry regimes, that help explain different types of technological/industrial change. The TEF will thus allow me to tackle, on the one hand, issues identified within the Greening of Industry literature (see section I.2), namely the 'inward focus' and 'determinism' of stage models of greening, and, on the other, issues that remain open in the third generation of issue life-cycle theory: lack of explanation about the shift towards substantive response (e.g. technological development) and about the interplays between the firm-level and the industry-level.[32]

This Chapter is structured as following: next section (III.2) is divided in two; it firstly (subsection III.2.1) discusses the main criteria for integrating the building blocks and then (subsection III.2.2) develops the conceptual framework based on a

[32] The third issue, of how to measure issue life-cycles will be addressed in the methodology, drawing on issue-attention cycles.

meta-analytical analysis of existing issue life-cycle models. I call my framework the 'Dialectic-Issue Life-Cycle' (DILC) model. The Chapter finish with concluding remarks (section III.3) that raise initial limitations to the model, which will be explored in the empirical chapters.

III.2. CONCEPTUAL FRAMEWORK

III.2.1. Criteria for integrating the building blocks

Geels (2010) distinguishes four positions regarding inter-theoretical combinations: (a) *complete integration* into an all-encompassing synthesis; (b) *incommensurability*, due to fundamental ontological differences; (c) *eclecticism*, pragmatic integration of bits and pieces without attention to compatibility issues; and (d) *crossovers*, which draws on interplays and complementarities between different theories. The 'crossover approach' was the criterion adopted in choosing TEF as a background framework, because, on the one hand, it enables me to position my contribution in the organizational field-level, a need identified in recent developments in the Greening of Industry literature. On the other hand, it provides a 'map', a guiding template for crossover integration of issue life-cycle theory with the other relevant literatures reviewed in Chapter II. Furthermore, in the review itself, I attempted to mobilize different theories in a complementary way, to address each other's shortcomings. Therefore, the first criterion for integration of the different building blocks is to aim for theoretical crossovers (position 'd' above), that is, I use concepts from different theories and literatures that may be regarded as complementary (or at least not incompatible, in that they are not based on opposing ontologies and epistemologies).

A second criterion, connected to this crossover approach, is provided by Poole and Van de Ven (1989), who suggest four ways of integrating different theories ('theory-building strategies'): (a) *opposition* of theories, in order to reveal insights about same phenomena; (b) *spatial separation*, which situates different theories (or theoretical insights) at different levels or positions in a framework (Geels, 2010); (c) *temporal separation*, which posits different theories in different moments in time; and (d) *synthesis*, which introduces new elements to make two or more theories compatible. My integration effort will draw on the second and third criteria. On the one hand, I will relate some insights to different levels of reference (e.g. firm-level or industry-level), on the other, I will use the TEF as a background framework and position insights from the different theories in it (e.g. STI theory will be used to conceptualize technology strategies in response to issue-related pressures, insights from Organizational Institutionalism will be used to conceptualize political strategies etc.). I will also draw on different theoretical concepts for each phase, to logically account for 'what goes on inside them' (e.g. some of the insights from technology-forcing policy theory apply to pre-enactment of regulation, others to the implementation phase).

The third criterion is that the model avoids a key short-coming of stage models: the determinism of life-cycle logics. Van de Ven and Poole (1995, p. 520-1) identified four 'pure types' (or ideal types) of models[33] that explain development and change in organizations:

> *1. A life-cycle model depicts the process of change in an entity as progressing through a necessary sequence of stages.* [...] *2. A teleological model views development as a cycle of goal formulation, implementation, evaluation, and modification of goals based on what was learned by the entity.* [...] *3. In dialectical models of development, conflicts emerge between entities espousing opposing thesis and antithesis that collide to produce a synthesis, which in time becomes the thesis for the next cycle of a dialectical progression.* [...] *4. An evolutionary model of development consists of a repetitive sequence of variation, selection, and retention events among entities in a designated population.* [...]

Van de Ven and Poole (1995) argue that each model posits a distinctive logic that accounts for different change aspects. They are thus incomplete, for they leave certain factors out of the model. Through the combination of two or more models, one can address individual deficiencies. To avoid the determinism of life-cycle models, I will draw on a dialectical metaphor for what goes inside each phase and between phases. My argument is that the shift from one phase to the next is not automatic or natural, but depends on conflict between those espousing change to address societal issues and those resisting changing. I therefore play on the notion of thesis and antithesis: some actors call for changes ('the antithesis') in the industry regime ('the thesis'). However, instead of reaching an immediate 'synthesis', in my model this dialectical process may escalate and spillover to different arenas during different phases, with more actors getting involved before

[33] In the organizational literature, models are rarely 'pure', as they often combine principles from two or more ideal types.

substantive changes in the industry regime takes place and a 'synthesis' emerge. In this sense, in each phase my model has to account to: (1) problem-related pressures; and (2) industry response strategies. It will also account for (3) drivers of phase shift.

I believe that these three criteria will allow me to build a coherent and consistent model that, together with my methodology, is able to address my research questions and thus make an original contribution to the field of STI policy research.

III.2.2. Towards the Dialectic Issue Life-Cycle (DILC) Model

III.2.2.1. Defining the number of stages

The first choice in building a new stage model of issue life-cycle is defining the number of stages. As we saw in Chapter II, existing issue life-cycle models range from three to five stages. In order to define the number of stages that my model will have, I will carry out a meta-analysis by plotting in parallel on a table the different stage models, with each one's similar stages aligned (Table III.1). While this meta-analytical exercise contains some dose of subjective interpretation, I took the approach of selecting as meta-stages those that (a) represent distinctive processes and (b) appear in most number of models. This analysis resulted in five meta-stages, which 'labels' (first column in Table III.1) are still very much connected to the issue evolution process, and therefore will be refined when I specify what goes within each stage: (1) Emergence; (2) Rising public concern; (3) Political debates; (4) Formation and implementation of policy; (5) Policy outcomes[34].

- The first stage is present in the works of Sethi (1975, 1979) and all works from the second (although Bigelow *et al.* (1991, 1993) merge emergence and interpretation into a single stage) and third generation, with the exception of Rivoli and Waddock (2011).
- The second stage is present in the works of Buchholz (1982), all works of the second generation, and Lamertz *et al.* (2003) (the models by Post (1978) and Rivoli and Waddock (2011) merge meta-stages 1 and 2).

[34] I thank Prof. Ben Martin for suggesting that the 'Outcomes' meta-stage would be better labelled as 'Policy outcomes'.

- The third stage is present in the works of Post (1978), Bigelow *et al.* (1991, 1993), Mahon and Waddock (1992), Lamertz *et al.* (2003), and Rivoli and Waddock (2011) (the models by Sethi (1975, 1979), Bigelow *et al.* (1997), and Mahon and McGowan (1996) merge meta-stages 2 and 3).
- The fourth stage[35] is present in the works of Sethi (1975, 1979), Bigelow *et al.* (1991, 1993), and Mahon and Waddock (1992), and, I argue, also in the works of Post (1978) and Rivoli and Waddock (2011), considering that litigation is part of the implementation process (Buccholz (1982) merges the policy formulation with the political debate stage).
- The fifth meta-stage is only mentioned by Sethi (1975, 1979), and Tombari (1984), and to some extent by Lamertz *et al.* (2003), who lump it together with the implementation stage. The inclusion of a fifth meta stage is a logical consequence: after the implementation process, it follows a certain outcome, which in a 'normal' issue life-cycle that progresses in the 'right' direction (towards addressing the issue in the 'synthesis') is the reorientation of the industry regime due to spill-overs to the task environment (via consumer demand or strict regulations). This characterization of the fifth stage anticipates the elaboration of what goes on in each stage and how the issue moves from on stage to the other, to which I turn next.

[35] I decided to attribute formation and implementation to a single phase because formation (enactment) takes place in the macro-political arena and happens after issues become 'hot' (Geels and Penna, 2013), representing – more than the culmination of the previous process of political debate – the beginning of a new phase, where an official framing has been articulated. This official framing is what informs the implementation process, which is executed by regulators at the executive government.

Table III.1: Summary of stage models of issue progression, with stages aligned in terms of their underlying characteristics

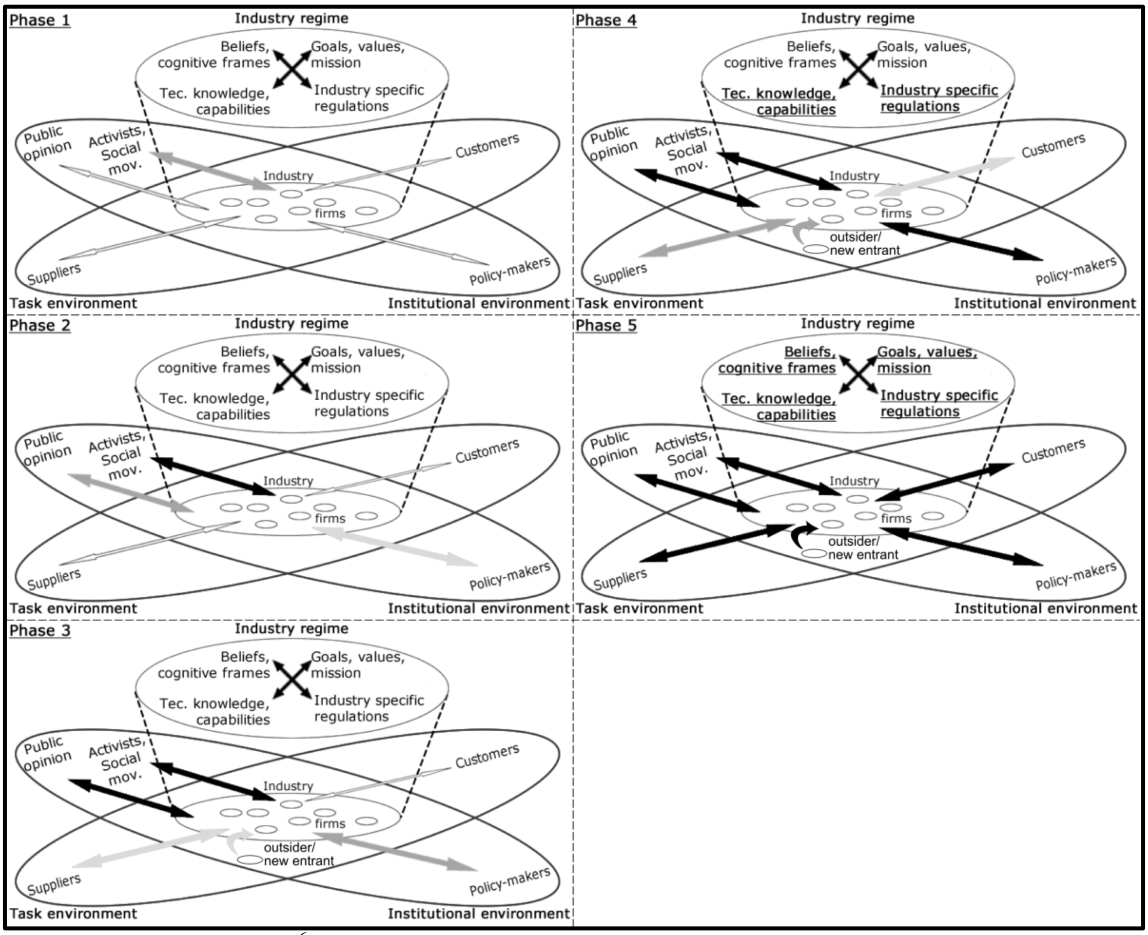
Meta-stage	1st Generation			2nd Generation			3rd Generation			
	Sethi (1975, 1979)	Post (1978)	Buchholz (1982)	Tombari (1984)	Bigelow *et al.* (1991, 1993)	Mahon and Waddock (1992)	Bigelow *et al.* (1997)	Mahon and McGowan (1996)	Lamertz *et al.* (2003)	Rivoli and Waddock (2011)
1 Emergence	Pre-problem	Emergence of expectational gap		Unnoticed or unattended need	Emergence Interpretation	Zone of rejection	Anticipatory	Introduction	Pressure on enacted structure	Gap
2 Rising public concern	Identification of 'legitimacy gap'		Public opinion formation	Awakened interest	Positioning	Zone of indifference	Emergence	Growth	Structural failure	
3 Political debates		Politicization (pre-legislation)	Public policy formulation	(Crisis) Massive attention		Zone of symbolic action			Issue definition	Political
4 Formation and implementation of policy	Remedy and relief	Legislative (and implementation) Litigation	Public policy implementation	(Solution introduced) Trial period	Resolution	Zone of substantive action	Enactment of policy Implementation	Entry into a specific arena Resolution	Institutional redesign Re-enactment: (i) issue resolution; (ii) issue perpetuation	Legislative (and implementation) Coping/ Litigation
5 Policy outcomes	(Prevention)			(i) Failure; (ii) Confidence; (iii) Apathy						

Source: Author's elaboration based on reviewed works.

III.2.2.2. Specifying the model: within-stage dynamics and phase shifts

The specification of the model is based on the three criteria outlined in Section III.2.1, namely: (a) the TEF, a guiding template for crossovers between issue life-cycle theory and insights from other literatures; (b) spatial and temporal separation of theoretical insights; and (c) the dialectics metaphor, which is both key for within-stage dynamics and phase shifts. Figure III.1 represents the five stages/phases of the *Dialectic Issue Life-Cycle* in terms of the TEF (cf. Figure I.1).

Figure III.1: Phases of the Dialectic Issue Life-Cycle model in terms of the Triple Embeddedness Framework



Source: Author's elaboration[36] based on the Triple Embeddedness Framework by Geels (2012a).

Obs.: Light-grey arrows indicate weak interactions or struggles, dark-grey arrows indicate moderate interactions or struggles, and black arrows indicate strong interactions or struggles. Underlined regime elements indicate changes in industry specific institutions.

The Figure indicates multi-dimensional interactions ('dialectics') between firms-in-industry and external stakeholders, which escalate as the issue evolves (light-/dark-

[36] A similar figure appears in Penna and Geels (2012), which however does not include the representation of outsider/new entrant in phases 3-5.

grey/black arrows), leading to changes in regime specific institutions (underlined core elements), beginning in Phase 4. The underlying logics is that societal issues first emerge in civil society via activists and then spill over to public opinion, creating some early credibility pressures on policy-makers who engage in symbolic action. Later on, these pressures lead to political debates, if the issue is still supported by activists, social movements and public opinion. So, the first three phases mainly take place in the socio-political arena (institutional environment), albeit in the third stage pressure starts to come from the task environment as well (through the actions of outsiders, new entrants and suppliers that respond to small demand by 'moral consumers').

In the first three phases, industry actors are reluctant to make substantial changes to address the issue, because they are 'locked in' to the industry regime. They therefore *collectively* respond with various defensive activities to protect the existing regime. When (forced to) acknowledge social problems (due to public pressures), individual firms-in-industry may move towards incremental solutions but will publicly resist substantial reorientation (and more radical innovation). In later phases, when the issue spills over to the task environment, industry actors gradually and *individually* move to more substantive responses to address the issue. In phase 4, action moves to the macro political arena, due to escalating public concern (attention), and politicians enact radical legislation that substantially changes the economic frame conditions (e.g. taxes, regulations, standards, subsidies, investments). The implementation process in phase 4 leads to the dynamic games between industry, outsiders and regulators (insights raised by the review of the technology-forcing policy literature). In phase 5, the problem affects mass markets (because of changing consumer preferences and/or because of regulation), which creates demand for radically new technologies. What follows is a complete reorientation (or 'recreation') of the industry regime: a synthesis of the whole dialectical process.

As mentioned, I propose that this is the 'normal' (Bigelow *et al.*, 1993) issue life-cycle: it represents an ideal-typical process in which dialectic struggles are accentuated, and the issue progresses in the 'right' direction, i.e. towards addressing the issue through regime reorientation. I now unpack this overall logic into specific dialectic dynamics for each phase and specify phase shifts.[37] The inclusion of industry response elements leads me to a new labelling for each stage. I also note the novelty of including an explicit discussion of processes that would indicate phase shifts: this is an attempt to address the lack of criteria for the delineation of phases, which is a gap that I identified in the review of issue life-cycle theory. Such 'phase shift processes' conceptually delineate the different phases of an issue life-cycle, and therefore represent *ex-ante* qualitative criteria (or indicators) for the identification of phases in an *empirical* issue life-cycle.

Phase 1: Problem emergence and industry neglect

Problem-related pressures: The initial stage is about changing expectations by some individuals, who begin to recognize the issue as such (Blumer, 1971; Post, 1978; Tombari, 1984; Bigelow *et al.*, 1991; Lamertz *et al.*, 2003). Affected groups, citizens, and other activists (Gerde and White, 2001), feeling a sense of urgency, first articulate concerns about a critical situation and frame it as a problematic condition. Issues are initially ill-defined and fuzzy; concerned activists do not fully grasp the implications of the facts that gave rise to the issue: there is much uncertainty about causes and consequences, so that these groups engage in sense-making (Sethi, 1979; Bigelow *et al.*, 1991; Lamertz *et al.*, 2003). Yet, sense-making is affected not only by facts, but also by common sense, values, beliefs and interests (Bigelow *et al.*, 1991). Because the wider public and policy-makers are unaware or indifferent to the issue, those activists continuously engage in transforming their 'private troubles' into public and policy (societal) issues (Spector and Kitsuse, 1973) through symbolic activities imbued with drama, such as demonstrations, campaigns etc. (Hilgartner and Bosk, 1988). Their goal is to engage the wider public and policy-makers, who at this stage are not concerned with the issue.

Industry responses: As activists are scattered and relatively powerless[38], firms-in-industries will initially downplay their demands and stay in their 'zone of rejection' (Buchholz *et al.*, 1994 [1985]; Mahon and Waddock, 1992; Rivoli and Waddock, 2011).

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[37] Somewhat different descriptions of the similar model specification appear in Penna and Geels (2012), Geels and Penna (2013) and Penna and Geels (2013). I here provide a *comprehensive* specification based on the building blocks of the literature review, which goes beyond and differs from the descriptions in these articles.

[38] Mitchell *et al.* (1997, p. 875) suggest that, in this stage, activists "are the 'mosquitoes buzzing in the ears' of managers: irksome, but not dangerous", i.e. not affecting primary or secondary involvement arenas.

If activist's claims become 'louder', the industry may attempt to change public expectations/perceptions (Sethi, 1975, 1979, Post, 1978) through public relations and other communication tactics that fall under the 'constituency building strategy'. However, the industry is unlikely to move beyond their 'zone of indifference' (Mahon and Waddock, 1992).

Phase shift: When activists coalesce into an organized social movement organization (SMO) (maybe after a 'crisis' or critical event – Tombari, 1984), the issue gains a new pace, due to the mobilization of resources around a particular issue-framing that spreads a public sense of urgency (Bigelow *et al.*, 1991; Greening and Gray, 1994; Lamertz *et al.*, 2003; Elzen *et al.*, 2011). The framing usually question the industry's institutions (e.g. their product or process technologies, or other regime elements), thus making it clearly accountable for the problem and questioning its identity (Hoffman and Ocasio, 2001; Lamertz *et al.*, 2003), triggering the dialectic process. This forces industry actors out of their zone of rejection *and* indifference, because the framing poses a threat to their 'shared identity' (Mahon and Waddock, 1992): antagonistic positions therefore start to be taken. Two factors therefore indicate phase shift: (a) emergence of a SMO that articulates (b) a particular issue framing that makes industry actors accountable for the societal problem.

Phase 2: Rising public concerns and defensive industry responses

Problem-related pressures: This is the stage of collective and organized pressure (Blumer, 1971; Bigelow *et al.*, 1991), whilst in the previous stage sense-making and campaigning activities were carried out by unorganized activists. SMOs organize demonstrations, educational campaigns and protests, and promote other framing strategies that add 'drama' to the issue (Hilgartner and Bosk, 1988). They may play on new scientific findings (Schneider, 1985) or issue-related shock-events that trigger wider public attention (Downs, 1972; Tombari, 1984) and lead to a shared sense of urgency. "In this phase, activists begin to attract the support of more 'mainstream' citizens and organizations, and these voices become too loud to ignore" (Rivoli and Waddock, 2011, p. 91). Public support adds 'legitimacy' (Mitchell *et al.*, 1997) to activists' demands, which creates reputation pressure on industry actors. A 'legitimacy' or 'performance' gap – between public expectations and industry practices – opens up (Sethi, 1975; Post, 1978; Sethi, 1979; Mahon and Waddock, 1992). In response to public attention, policy-makers may start to engage in symbolic action (Mahon and Waddock, 1992), e.g. express concerns or promote public campaigns and conferences to discuss the issue. This action is however not sufficient to address the problematic condition or force the industry to do so.

Industry responses: Firms-in-industries move out of their zone of rejection/indifference and into the zone of symbolic action (Mahon and Waddock, 1992), which represent defensive strategies to defend themselves against criticisms and pressures stemming from the institutional environment. They may use "de-dramatizing strategies" (Hillgartner and Bosk, 1988, p. 62) and promote advocacy advertising, public relations, press conferences, or political education programmes (Hillman and Hitt, 1999) that aim at reframing the problem (Mahon and Waddock, 1992). Therefore, an early 'framing struggle' opens up when firms in the industry position themselves around an alternative issue framing (Lamertz *et al.*, 2003) that favours the *status quo*. Which framing "comes to dominate public discourse has profound implications for the future of the social problem, for interest groups involved, and for policy" (Hilgartner and Bosk, 1988, p. 57-8). Due to the reputation threat posed over the entire industry, firms will likely form an Inter-Organizational Relationship for reasons of legitimacy (Oliver, 1990): a closed industry front to protect collective interests against issue-related pressures.

At this stage, if further denial damages their credibility, individual firms may start to perceive a need to allocate some R&D resources towards incremental innovations (Freeman and Perez, 1988) that stay within the bounds of the existing industry (technical) regime, thus allowing them to exploit existing competencies (March, 1991). On the one hand, this is a defensive strategy that promotes a favourable (technical) issue-framing to prevent deeper changes in the regime. On the other, it plays a symbolic role, as it signalizes the 'industry is working towards solution' and thus no forced (political) mandate shall be needed (Maxwell *et al.*, 2000). In other words, 'greenwashing' and display of incremental technical prototypes is a possible strategy at this point (Schrage, 1993; Laufer, 2003).

Phase shift: The move to the next stage is marked by public issue-attention moving above a certain threshold, indicating shared public concern that creates pressures on policy-makers. In other words, the issue spills-over from civil society to the policy domain (Neuman, 1990). Key mechanisms leading to rising public attention are *framing struggles*, *organized action by SMOs* and *reportage by the media* (Lamertz *et al.*, 2003; Rivoli and Waddock, 2011): "As activism continues, the media tends to take more notice, raising it in public awareness and increasing the likelihood that institutional processes will be set in place. (...) Thus, the issue is propelled into the next phase" (Rivoli and Waddock, 2011, p. 92).

Phase 3: Political debates, controversies and defensive hedging

Problem-related pressures*:* With positions established around alternative framings, the struggle becomes one of influencing the *official* framing adopted by policy-makers. These struggles take place in policy debates, inquiries and public hearings to investigate causes and possible solutions. Activists, SMOs, scientists and other concerned actors (including industry representatives) all take part in this political debate process, deploying information, direct lobbying and financial incentives strategies (Hillman and Hitt, 1999). Political debates in investigative hearings represent heated framing struggles (Blumer, 1971) that reflect interpretations based on values, beliefs and interests as much as facts (Bigelow *et al.*, 1991; Lamertz *et al.*, 2003). The visibility of this debate leads to escalating public attention (Downs, 1972).

Another (yet incipient) source of pressure on the industry begins to appear in the task environment, as public concerns may lead to the emergence of small lead markets for radical alternatives – constituted by what may be called 'moral consumers' – which will initially be seized by industry outsiders (including suppliers attempting to expand their own markets) (Geels, 2002; Tidd *et al.*, 2005; Gerard and Lave, 2007; Lee *et al.*, 2010).

Industry responses*:* Although the industry front is active in defending the regime, individual firms accelerates their technical learning activities during this stage. They thus adopt 'hedging strategies': *collective* political strategies take the form of releasing technical information (e.g. testifying as expert witness in hearings) to influence the official framing; this may include withholding relevant (technical) information from policy-makers, with the industry thus playing on 'information asymmetry' between the industry and policy-makers (Puller, 2006). It also includes lobbying, and other information campaigns; due to the beginning of processes in the task environment, these activities draw on the alternative issue framing as much as on economic factors, e.g. supposedly high costs and infeasibility of technical solutions that go beyond incremental innovations. As industry outsiders have also started to work on alternative solutions (in response to the initial consumer demand), cost or feasibility arguments may be contested by outside specialists who also take part in the debate, because these outsiders have interest in seeing a regulatory mandate approved (Lee *et al.*, 2010).

Individual firms may also engage in more *substantive* strategies through the exploration (March, 1991) of radical technical alternatives. They can promote internal R&D investments (e.g. creation of specialized departments) or seek partnerships ('joint-ventures') with specialist firms if the field of knowledge necessary to promote a radical solution falls outside the incumbent's (background or core) competences (Prencipe, 1997; Dyerson and Pilkington, 2005). This is still hedging though, aimed at preparation for future eventualities. As the closed industry front is still maintained for reasons of asymmetry [39] (between the industry and policy-makers), such individual initiatives are expected not to be as visible as outsiders' developments.

Phase shift: The shift to the next phase entails the problem moving onto the macro-political agenda (True *et al.*, 1999), which requires the problem to further 'heat up', with public attention approaching a peak (Post, 1978; Tombari, 1984). The same mechanisms of 'attention advocacy' (Lamertz *et al.*, 2003) make the issue hot and lead to surges in attention: activists and SMOs playing on scandals and shock events, visible dialectic struggles, and the media publicizing all of these. High public attention attracts policy entrepreneurs (Kingdon, 1984) and high-level politicians to the process: proposing and leading the enactment of substantive policies to tackle a hot issue is often a source of positive popularity and an advantage during election cycles. A second indicator of phase shift is the existence of a (technical) solution (usually the result of outsiders' work), which also promotes the issue to the top of the macro-political agenda (Kingdon, 1984). In fact, the existence of a radical technical solution (even in theory) *which has not yet been brought to markets* is a key motivation for developing substantive regulations, e.g. technology-forcing policies.

[39] The IOR is also maintained for reasons of (Oliver, 1990): reciprocity (between industry actors, e.g. to prevent a single firm to gain economic advantage based on the issue), efficiency (to avoid duplication of political strategy efforts) or for stability and predictability of future outcomes (in case the collective effort succeeds).

<u>Phase 4: Formation and implementation of substantive policy and industry diversification</u>

***Problem-related pressures**:* Macro-politicians get involved during the peak of public attention to the issue, in a self-reinforcing 'me-too' process: increasing public attention leads politicians to act, which leads to more public (and media) attention. The political debate gets more evident when media become interested in technical hearings and investigative committees, leading to a highly visible struggle to shape the policy plans (Blumer, 1971). The combination of the issue acquiring a 'celebrity status' (Geels and Penna, 2013) and a high sense of urgency (e.g. public outrage and convergence of attention) help to create the political will to enact radical policy (Molitor, 1977).

The symbolism of enacting a radical piece of regulation "may cool down the controversy and make the issue less visible in the mass media" (Spector and Kitsuse, 1973, p. 153). This is the turning point in the process (Post, 1978; Tombari, 1984; Rivoli and Waddock, 2011), when public attention diminishes as the issue moves to the backstage of administrative agencies. In qualitative terms, the issue becomes institutionalized through the new legislation, so that attention can be easily redrawn in case new controversies arise (Downs, 1972; Spector and Kitsuse, 1973). And yet, even if a radical piece of legislation has been enacted, "the matter is by no means settled" (Post, 1978, p. 24), because the mandate still has to be interpreted and implemented. In the task environment, the new market niche starts to gain momentum, with demand from concerned consumers spilling over to mainstream markets, which represent important entry or leverage point for firms.

***Industry responses**:* This stage sees the rise of a new struggle between individual firms' strategies and the collective industry strategy. Initial tensions from the past stage lead to several types of strategic games in the industry's environments. Existing industry association (IOR) may continue to deploy political strategies towards the institutional environment, to delay or prevent implementation of regulations, and to ratchet down the regulator's credibility (Puller, 2006): this is the time of confrontational strategies, which include non-compliance, blackmailing and litigation (e.g. to contest the legislation that might be mandating a technology still not fully developed – Gerard and Lave, 2007).

Yet, individual firms' technological strategies are likely to move beyond hedging and towards diversification, with increased R&D investments in radical alternatives, to seize the growing consumer market for the 'technical solutions'. Individual firms start to 'jockey for position' – to secure a first-mover advantage over its rivals – and attempt to transform their own radical technology into *de facto* standard (Puller, 2006; Gerard and Lave, 2007). Permanent cracks start to appear in the industry front, possibly leading to the complete dissolution of the issue-specific IOR towards the end of this stage. The industry regime's technical and regulatory elements are at this point substantially changed.

Phase shift: The permanent crack in the industry front (resulting from the new dialectical struggle) is a first indicator of phase shift, revealing that the issue has crucially spilled over to the task environment. Another indicator is the end of a period of regulatory (Lee *et al.*, 2010) and technical uncertainties, i.e. when the radical policy is effectively implemented and there is a single technical solution towards which firms reorient. This regulatory and technological convergence may result in innovation races. Competitive struggles, mandated markets (through regulation) and spillover from niche markets lead to more substantive changes in mainstream consumer preferences and higher demand for radical technological alternatives. So, a third indicator is the visible acceleration of market demand.

Phase 5: Spillovers to the task environment and industry 'recreation'

Problem-related pressures*:* This is the outcome stage, when radical technologies diffuse to mainstream markets, either (a) through a strict policy (regulation) or (b) through changes in consumer preferences. Socio-political pressure diminishes considerably, and attention declines. With the social and political institutionalization of the issue, new behaviours and cultural ideologies (e.g. environmentalism) affect consumer preferences. These also change as a result of marketing positioning efforts by the industry and price/performance improvements that make new technologies more attractive (Geels and Penna, 2013).

Industry responses*:* Industry regime reorientation is the result of individual firms perceiving a new issue-related market opportunity, which incentivizes them to enact new institutions and strategies. Firms change economic positioning strategies, which now encompass the promotion of the new technology – an innovation race is now at full speed. On top of changes in the technical and regulatory elements, the regime's core beliefs and mission are now substantially transformed (e.g. there is a widespread belief that addressing the issue is economically and technically feasible, so that it becomes part of the industry's mission to do so). The issue life-cycle thus results in the 'strategic recreation' (Tushman and Romanelli, 1985) of the incumbent industry regime.

III.3. CONCLUDING REMARKS

The Dialectic Issue Life-Cycle model specified above aimed at addressing a gap in the STI field of research so as to contribute to the 'Grand Societal Challenges' agenda. The gap concerned how societal issues co-evolve with technology and how the incumbent industry may contribute to addressing these issues. I used the Greening of Industry literature as an inspiration, which suggested that issues and responses progress through stages at the organizational field level. Due to shortcomings in this literature, I reviewed issue life-cycle theory, which however presented three shortcomings of its own. Through the mobilization of insights from additional works (from STI studies and Organizational Institutionalism), the DILC-model manages to address these three shortcomings: it explains the shift towards substantive response (e.g. technological strategy) by incumbents; it relates the dynamics of issue attention to patterns (stages and shifts) of an issue life-cycle (a point further explored empirically); it explains the interplays between firm-level and collective (industry-level) strategies; and it proposes qualitative criteria ('phase shift processes') for the identification of stages (which will be further explored methodologically and empirically). The DILC-model therefore represents a first-round – conceptual – answer to this thesis' research questions.

While the ideal type DILC-model offers an important (conceptual) approximation to answering the research questions, it also has two explicit shortcomings: (1) it does not take into account the influence of wider contexts and competing issues on a given issue life-cycle; and (2) it posits a linear ('normal') pathway to an issue life-cycle. Both shortcomings will therefore be tackled empirically: these tentative answers to my research questions will be tested and refined through the application of the DILC-model to empirical cases, which will take into account influence of wider contexts and look for non-linear pathways.

The latter therefore represents an important criterion for case selection. Next Chapter will outline the methodology that I will use to test the model, in order to arrive at more nuanced answers to the research questions.

A possible criticism to the DILC-model regards its *complexity*: the model builds upon the Triple Embeddedness Framework and combines insights and concepts from multiple fields, literatures and theories. To be useful, a model (just like a map) should simplify the complex reality (territory) by identifying key concepts, possible mechanisms, and their relationships. The importance of simplicity is particularly important for 'grand theories' that aim to explain a wide range of phenomena (for instance, neoclassical economics, which explains economic phenomena based on a few assumptions about individual and corporative behaviour). This is *not* the ambition ascribed to the DILC-model, which aims at middle-range theorizing[40]: it addresses a particular type of phenomena – issue life-cycles and the strategic responses of industries, with particular attention to technological development, and it does so by defining an interrelated set of propositions that relates different concepts into a coherent whole. At this point of theoretical development, the DILC-model is more complex than what would be expected from middle-range theories, which are based on a limited number of related concepts and stylised facts (Geels, 2007, p. 635). While the model scores low on simplicity, it aims to score high on accuracy, so that its use in combination with an appropriate methodology (which I will develop in the next Chapter) shall enable a clear link to empirical cases and its testing. This empirical analysis shall enable the identification of patterns, regularities, and mechanisms that can be used to further refine and simplify the model.

[40] The notion of 'middle-range theory' was introduced by Merton (1949) and became an important theoretical avenue for the development of science and technology studies (STS) (on middle-range theories, with a particular focus on STS, see discussion in Geels, 2007).

IV. METHODOLOGY

This chapter presents the methodology for application, testing and refinement of the DILC-model. It starts with an outline of my ontological commitments and epistemological assumptions, which result in a choice of utilizing Process Theory methods. I will apply the DILC-model through a narrative method and through quantitative methods (or 'quantification approach'). In particular, the quantification approach seeks to investigate a gap in issue life-cycle theory: how attention to an issue fluctuates throughout the issue life-cycle. As this is an underdeveloped topic in existing theory, I propose the utilization of three quantification methods to investigate the relationship between issue-attention cycles (including technology hype-cycles) and issue life-cycles. The new methodology represents a potential original contribution. The Chapter ends with a presentation and discussion of the case study design, including case selection, protocol and analytical strategies.

IV.1. ONTOLOGICAL COMMITMENTS AND EPISTEMOLOGICAL ASSUMPTIONS

Any theory-building and research enterprise rests on ontological commitments and epistemological assumptions on part of the theorist and researcher. Therefore, this section spells out my commitments and assumptions, which allow me to link the theoretical framework to the methodology that I will use to analyse empirical cases and test the theory.

Bennett and Elman (2006a, p. 250) argue that methodologies "must take into account the characteristics of the phenomena we seek to understand", which implies, at least, certain 'ontological commitments' (Hofweber, 2013) on part of the researcher.[41] "[S]cholars have beliefs about what the social world is made of and

[41] I say 'at least', because ontology can be conceived of four parts: "(O1) the study of ontological commitment, i.e. what we or others are committed to, (O2) the study of what there is, (O3) the study of the most general features of what there is, and how the things there are relate to each other in the metaphysically most general ways, (O4) the study of meta-ontology, i.e. saying what task it is that the discipline of ontology should aim to accomplish, if any, how the questions it aims to answer should be understood, and with what methodology they can be answered" (Hofweber, 2013, *online*). The importance of spelling out one's own ontological commitment is that it brings with it implications for how to proceed when answering non-ontological questions, i.e. ontological commitments have epistemological implications. While the other definitions (O2-O4) certainly bring about similar implications, these are concerns of deep philosophical and metaphysical debates, which go beyond the limited scope and purpose of this brief ontological discussion.

how it operates, and these beliefs influence their choices about how to construct and verify knowledge statements about that world" (Bennett and Elman, 2006b, p. 456-7). The key ontological commitment is about what constitutes the 'nature of reality'. In the context of this thesis, which is concerned with institutional (i.e. the industry regime), organizational (i.e. firms-in-industries) and technological changes in response to societal problems, it is therefore sufficient to digress about the nature of *institutions*, *organizations*, *technologies* and *problems*.

Van de Ven and Poole (2005) identify two foundational ontological positions: one that sees the nature of reality as consisting of *things* and another that sees it as consisting of *processes*. In fact, both things *and* processes form part of the reality, but assumptions regarding how they interact result in quite contrasting views of the world: in one view, the "world [is] made of things in which processes represent change in things", in the other view, the "world [is made] of processes in which things are reifications of processes" (Van de Ven and Poole, 2005, p. 1379). Van de Ven and Poole (2005, based on Chia and Langley (2004) and Tsoukas (2005)) call the first view the 'weak' form of a 'process approach'; while the second view represents the 'strong' form of a 'process approach'. In this thesis, I adopt the weak form of a process approach. Indeed, the DILC-model is a process-based explanation of changes through which the relevant entities or 'things' (institutions, organizations, technologies and problems) go over time.

My ontological commitment therefore is to this process-based view of the world, but my epistemological assumptions are based on 'Critical Realism'[42] (Bhaskar, 1978; Lloyd, 1989; Reed and Harvey, 1992; see also Mutch, 2005): while I see 'things' as the result of socially constructed 'processes', I do not subscribe to a worldview in which 'everything is a social construction' (Burnes, 2009) that can/should only be analysed as such. That perspective can be exemplified

> *...in terms of the structure and operation of organisations. Realists argue that a structure is a set of simultaneously enabling and constraining rules and resources which shape the interactions of those who work in or have to deal with the organization. That is to say, a structure can be considered as a causal mechanism which has the potential and capability to act in certain ways, i.e. it has causal powers* (Burnes, 2009, p. 181)

[42] Burnes (2009, p. 179-182) provides a good summary of the Critical Realist perspective in Organization Studies.

In other words, in this critical-realist perspective, structures possess a causal power that condition but do not determine social interaction and processes (Mutch, 2005). But “structures cannot produce and reproduce themselves” (Lloyd, 1989): this requires individual and collective human action. Bhaskar (1989, p. 76) gives the example of societies, which are not created by individuals, “[f]or it always pre-exists them and is a necessary condition for their activity. Rather society must be regarded as an ensemble of structures, practices and conventions which individuals reproduce and/or transform. But which would not exist unless they did so. Society does not exist independently of human activity… But it is not the product of it…”. Society is a thing that exists when reproduced or transformed through processes.

In my approach, I assume there is a ‘reality’ out there to be analysed in terms of causal mechanisms (process). Yet, this analysis is dependant upon the observer’s (my) point of view (including knowledge, understanding, experience etc.) – therefore, it is a ‘critical’ analysis. What are the implications of this critical realist view for institutions, organizations, technologies and problems? First of all, they all can be seen as entities or structures – socially constructed through processes – that enable and constrain action, but which need constant enactment through individual or collective human action to exist. Industry regimes (a set of institutions), for example, enable and constrain individual organizations’ (firms’) strategic action; but strategic action by individual firms is what produces, reproduces or transforms the industry regime. Technologies (and technical regimes) are socially constructed (Bijker *et al.*, 1987) in similar fashion, and, once constructed, enable and constrain – but not determine – action. They thus have causal power that needs to be constantly actualized. The same is true for societal problems or issues: they are socially constructed in certain ways that frame a given condition as problematic, and ascertain causes and effects to this problematic condition (Hilgartner and Bosk, 1988). A condition can be framed as problematic in many ways, and therefore any particular framing needs to be constantly actualized and reaffirmed in light of competing framings.

Secondly, once created or constructed, an institution, organization, technology or problem become an entity “that retains its identity while changing from one state to another over time” (Van de Ven and Poole, 2005, p. 1380). This is what permits an observer to speak of industry, organization, technology or issue 'life-cycles' and assign them certain capabilities. Therefore, my ontological commitment brings about an epistemological consequence: the task of the 'realist researcher' becomes one of identifying (a) the real capabilities or causal powers or entities under analysis (i.e. institutions, organizations etc); and (b) the generative structures and processes – causal mechanisms – underlying these entities (Burnes, 2009). This social scientific enterprise "takes place within frameworks [...] which help conceptualize objects of inquiry and the form of explanations" (Lloyd, 1989, p. 465).

Which epistemological position allows for the identification of causal mechanisms and causal powers underlying change processes in institutions, organizations, technologies and issues? It is useful to distinguish between two epistemologies (Abbott, 1992; Van de Ven and Poole, 2005), which are clearly linked to different ontological assumptions: (1) change can be understood through the lenses of 'Variance Theory'; or (2) it can be understood through the lenses of 'Process Theory'. The first one represents change as a dependent variable to be explained in terms of a set of independent variables. The second view takes change as an unfolding process composed of a sequence of events that happen in an institutional arrangement and result in a given outcome (Van de Ven and Poole, 2005). Table IV.1 compares both theoretical approaches in terms of epistemological assumptions (focus, types of explanation, criteria for generalizations, importance of time and time-related factors etc.) (Poole *et al.*, 2000; Van de Ven and Poole, 2005):

Table IV.1: Comparison of Variance and Process Approaches

Variance Approach	Process Approach
Fixed entities with varying attributes	Entities participate in events and may change over time
Explanation based on necessary and sufficient causality	Explanation based on necessary causality
Explanations based on efficient causality	Explanations based on final, formal, and efficient causality
Generality depends on uniformity across contexts [cases]	Generality depends on versatility across cases [contexts]
Time ordering among independent variables is immaterial	Time ordering of independent events is critical
Emphasis on immediate causation	Explanations are layered and incorporate both immediate and distal causation
Attributes [variables] have a single meaning over time	Entities, attributes, events [variables] may change in meaning over time

Source: Poole *et al.* (2000, p. 36, *apud* Van de Ven and Poole, 2005)

- The *Variance Approach* assumes that all significant *change can be captured by variables*. It focuses on *fixed entities with varying attributes*, and therefore those *variables have persistent meanings* throughout the period under study. Explanations take the form of *deterministic causal statements* or (linear) models (e.g. 'X causes Y', or '$Y = \alpha + \beta X + \varepsilon$') that aim at *establishing necessary and sufficient conditions* for the (change) outcome. Studies based on variance method are interested in *finding 'efficient causes'*: what or who (which independent variable) caused the outcome (dependent variable). Because the *focus is on immediate causality* and stable attributes and relationships, *time and chronological ordering of factors (variables) do not affect results*. Given the precision with which statements and models are constructed, *generality is dependent upon uniformity* across context and cases, and therefore a main criterion for assessing the value of a variance model is its *predictive power*.

- The *Process Approach* sees *change as a sequence of events*, which is *best captured by 'narrative histories' or stories* rather than variables (Van de Ven, 2007). These *account for temporal connections* among entities, attributes and events, which may *change in meaning over time*. *Time and chronological ordering of events is crucial* in the process approach (Pettigrew, 1997). "A process theory needs to go beyond a surface description, to penetrate the logic behind observed temporal progressions. This explanation should identify the generative mechanisms that cause observed events to happen in the real world, and the particular circumstances or contingencies when these causal mechanisms operate…" (Van de Ven and Poole, 2005, p. 1385). Explanations "may incorporate several different types of effects […], including critical events and turning points, contextual influence, formative patterns that give overall direction to the change, and causal factors that influence the sequencing of events" (*idem*, p. 1384). Causal explanations thus account for *'efficient causes'*, plus *formal causes ('formative patterns')* and *final causes ('overall directions')*.[43] Here, *generality* depends not on

[43] The 'Four Causes' are an epistemological principle conceived by Aristotle, who posits that knowledge of a thing is only achieved when its causes are grasped. To guide scientific enquire, Aristotle suggests four kinds of answers to why (causality) questions; things have: "The material

> uniformity and predictability but on *versatility*: "the degree to which it can encompass a broad domain of developmental patterns without modification of its essential character" (Poole *et al.*, 2000, p. 43).

From the above description, it is clear that the epistemological approach most suitable to my ontological commitments and research enterprise is Process Theory. My research is interested in how industries and technology change (or not) in response to societal issues. The co-evolution of societal problems with industries and technologies is complex and multi-dimensional phenomena that operate in long timeframes. More than aiming at the identification of antecedent and consequent factors (variables) of such change processes, I want to understand *how this process unfolds* and its generative mechanisms. To understand the dynamics of change over time, 'process theory' is more appropriate than methods that aim at testing causality between variables (Abbott, 1992; Pettigrew, 1997; Langley, 1999). Process theory "offers an explanation of the development and change that encompasses continuous and discontinuous causation, critical incidents, contextual effects, and effects of formative patterns" (Poole *et al.*, 2000, p. 4).

I thus arrive at an epistemological criterion for accessing the suitability of the DILC-model: it shall be suitable for carrying processual research. Pettigrew (1997, p. 340) proposes five guiding principles (or assumptions) for conducting processual analysis:

> *1. embeddedness, studying processes across a number of levels of analysis;*
> *2. temporal interconnectedness, studying processes in past, present and future time;*
> *3. a role in explanation for context and action;*
> *4. a search for holistic rather than linear explanations of process; and*
> *5. a need to link process analysis to the location and explanation of outcomes.*

The Dialectic Issue Life-Cycle meets all five principles:

1) Drawing on the TEF, the model shows that the co-evolution of societal issues, industry and technologies is a multi-dimensional process embedded in two environments. The DILC-model also accounts for processes at different levels

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cause: 'that out of which', e.g., the bronze of a statue. The formal cause: 'the form', 'the account of what-it-is-to-be', e.g., the shape [and e.g. proportions] of a statue. The efficient cause: 'the primary source of the change or rest', e.g., the artisan, the art of bronze-casting the statue, the man who gives advice, the father of the child. The final cause: 'the end, that for the sake of which a thing is done', e.g., health is the end of walking, losing weight, purging, drugs, and surgical tools" (Falcon, 2012: *online*).

(e.g. individual/collective; organizational/industry), thus allowing for a multi-level analytical approach.

2) The DILC-model shows that the co-evolution of societal issues, industry and technologies is a long-term process that unfolds in stages, so that changes have distal and immediate causes.
3) By drawing on the TEF, the DILC-model recognizes multiple environments, levels and entities, showing that the co-evolutionary process under analysis is the result of contextual and enacted causes.
4) The factors above together makes the DILC-model a 'big picture' holistic framework (or 'ideal type') for the study of how societal issues, industry and technologies co-evolve.
5) The model is geared towards outcomes: outcomes of dialectic process *within* stages and of the *whole* dialectic issue life-cycle process.

Establishing point (5) – linking the processual analysis to outcomes – requires the development of suitable methodology based on specific methods. This will allow me to apply and test the DILC-model in empirical cases. I now turn to the specification of these 'process theory methods'.

IV.2. PROCESS THEORY METHODS

Process theory represents an epistemological approach in the Social Sciences that may be applied to empirical analysis through an array of methods, which can be referred as 'process theory methods'. Langley (1999) identifies seven process methods – or what she calls 'strategies for sense-making' of process data: 'narrative strategy'; 'quantification strategy'; 'alternate templates strategy'; 'grounded theory strategy'; 'visual mapping strategy'; 'temporal bracketing strategy'; and 'synthetic strategy'. Each of these is defined in terms of 'key anchor point', 'fit with process data complexity', 'specific data needs', and key 'form of sense-making' (see below). In fact, Langley (1999) argues that these strategies are suitable for developing new process theories or frameworks, but each has strengths and weaknesses depending on their level of 'accuracy', 'simplicity' and 'generality'. The combination of multiple methods therefore has the potential of diminishing weaknesses by drawing on distinctive strengths. In applying the DILC-model to empirical cases, I therefore will use two methods that can be seen as complementary: the 'Narrative Approach' and the 'Quantification Approach'.[44]

IV.2.1. The Narrative approach

The narrative method entails the construction of a detailed story based on (primary and secondary) data collected. Poole *et al.* (2000, p. 12) eloquently explains key steps in a research enterprise based on process theory and the role played by the 'narrative' in a processual analysis:

> *...investigators gather data that indicate how the process unfolds over time. Some of this data could be in the form of quantitative measurements of key variables, but other data would consist of detailed descriptions of the events that constituted change and development of the entity under study. Based on these descriptions, researchers construct a timeline of events that were significant in the development and change process. Each case will have a unique timeline, and real or apparent differences among cases are a major focus of the study. Instead of treating unique features of a case as sampling error, a process study attempts to identify the circumstances that created the particular twists and turns in each ease. The flow of events and the conjunctions of causal forces that move the developing entity through its sequence are captured in a narrative that explains the case.* (my emphasis)

The narrative does not consist of a descriptive story void of explanatory content – a mere 'sequence of events'. It is rather an 'analytical chronology', which explicitly and purposively interprets the process data (Pettigrew, 1990) in order to arrive at a 'mechanism-based' explanation. The narrative approach therefore "does not aim at an exhaustive account of all details but seeks to capture the crucial elements of the process by abstracting away the irrelevant details" (Hedström and Ylikoski, 2010, p. 53). The researcher thus uses the narrative to identify *generative structures and mechanisms* that enable and constrain action and results in certain – but not unique – outcomes, depending on the chronology of events and ordering of processes (Verhees, 2011).

The narrative approach is a type of 'process tracing' method that tests a mechanism-based theory (Hedström and Ylikoski, 2010): the method consists of (1) reconstructing the development of empirical process(es) over time and identifying its (their) chain of causal mechanisms (Kern, 2009); and (2) comparing this

[44] My methodology also draws on 'visual mapping', as it will analyse the ordering of factors (namely, 'attention' indicators) through time; and 'temporal bracketing', as it anchors core part of the analysis on 'phases/stages'. However, I embed the latter in both the narrative and quantification strategies, and the former in the quantification strategy.

empirical result with the process theory or framework. “In process tracing, the researcher examines histories, archival documents, interview transcripts, and other sources to see whether the causal process a theory hypothesizes or implies in a case is in fact evident in the sequence and values of the intervening variables in that case” (George and Bennett, 2005, p. 6). Most of the time process tracing through a narrative takes the form of an ‘in-depth case study’ (Pettigrew, 1990; Yin, 2003), which requires a case study ‘template’ or ‘protocol’ (see section IV.3) based on the theoretical framework which is being tested (the DILC-model, which is a ‘theoretical narrative’). It is this protocol that enables pattern-matching between empirical case and theory and cross-case comparisons (see section IV.3.3).

In terms of Langley’s (1999) typological assessment of process theory methods, the narrative approach can be characterized as following: given the importance of ‘chronology’, its key anchor is ‘time’. Because the narrative allows the researcher to account for distal and ambiguous causes, the method presents good fit with ‘ambiguous boundaries’ and ‘variable temporal embeddedness’. Moreover, the application (and testing) of theory through the narrative method requires one or few rich (‘in-depth’) cases that allow theory-testing through comparison. In terms of ‘sense-making forms’, the narrative method draws on ‘stories’, ‘meanings’ and ‘mechanisms’. While the strength of narrative approach lies in its *accuracy*, it is weak in simplicity and generality (in the sense of ‘uniformity across contexts’). The use of a ‘quantification approach’ helps to address some of these weaknesses: “[t]he two strategies […] lie at the two ends of a continuum that opposes empirical accuracy and theoretical parsimony” (Langley, 1999, p. 698).

IV.2.2. The Quantification approach

In Langley’s (1999) typology, a ‘quantification strategy’ is anchored on ‘events’ and ‘outcomes’: by presenting good fit with – and focusing on – ‘events and their characteristics’, it ‘eschews ambiguity’. This method requires many similar events (or relatively long time series) for statistical analysis, and therefore one or few dense cases are suitable for theory development and testing. Sense-making through a quantification strategy has the potential to reveal initial patterns and mechanisms. By eschewing ambiguity and abstracting from original data, this method scores high on *simplicity* and *generality*, but low on accuracy.

The quantification strategy is often used as a 'variance theory method'. Yet, it may also be used within a process epistemology and methodology. For instance, Van de Ven and Poole (2005) mentions the use of 'agent-based models' to test process theories; and Langley (1999) refers to methods based on 'coding' (e.g. of events or words), which result in time series of similar factors that can be statistically analysed. She notes, however, that "despite the conversion of the data to quantitative form, the types of statistical analysis appropriate to process theorizing are somewhat different from those used in most variance research" (Langley, 1999, p. 687). While variance theory relies on standard statistical methods – such as ANOVA (ANalysis Of VAriance) or linear regressions – that seek to test and generalize an uniform theory *across cases*, process theory quantification methods use time-series and experimental statistical methods – such as lagged regression, log-linear models, non-parametric statistics, autoregressive models, and dynamic simulation such as agent-based models – *within a single case* (Langley, 1999).

However, "[t]he quantification strategy will be much more convincing if it is used in combination with other approaches that allow contextualization of the abstract data, adding nuances of interpretation and confirming the mechanics of the mathematical model with direct evidence" (Langley, 1999, p. 698). Accordingly, in this thesis, I will use the quantification approach as part of my in-depth case study methodology: it will be used to examine initial relationships and patterns to be further explored with the narrative method.

The main goal of using these mixed (qualitative-quantitative) methods is to address two gaps in issue life-cycle theory, identified in Chapter II: the relationship between issue life-cycles and issue-attention cycles (including technology hype-cycles); and criteria for the identification of empirical phases. Because these are gaps in existing theory, I will develop an original methodology based on three increasingly sophisticated quantification methods: (1) *visual analysis of time series*; (2) *meta-correlation analysis within a temporal bracketing framework*; and (3) *testing for unknown structural breaks in the time series*. To my best of knowledge, the use of these methods (in separation or in combination) within an issue life-cycle framework has not been attempted before, and thus this novel methodology can potentially represent an original contribution of this thesis, as it may help to establish the relationship between issue-attention cycles and issue attention life-cycles, while also providing a method to objectively identify stages in an empirical issue life-cycle. In order to test the feasibility and usefulness of these methods, I will select cases that allow their application (see section IV.3.1).

IV.2.2.1. Visual analysis of time series

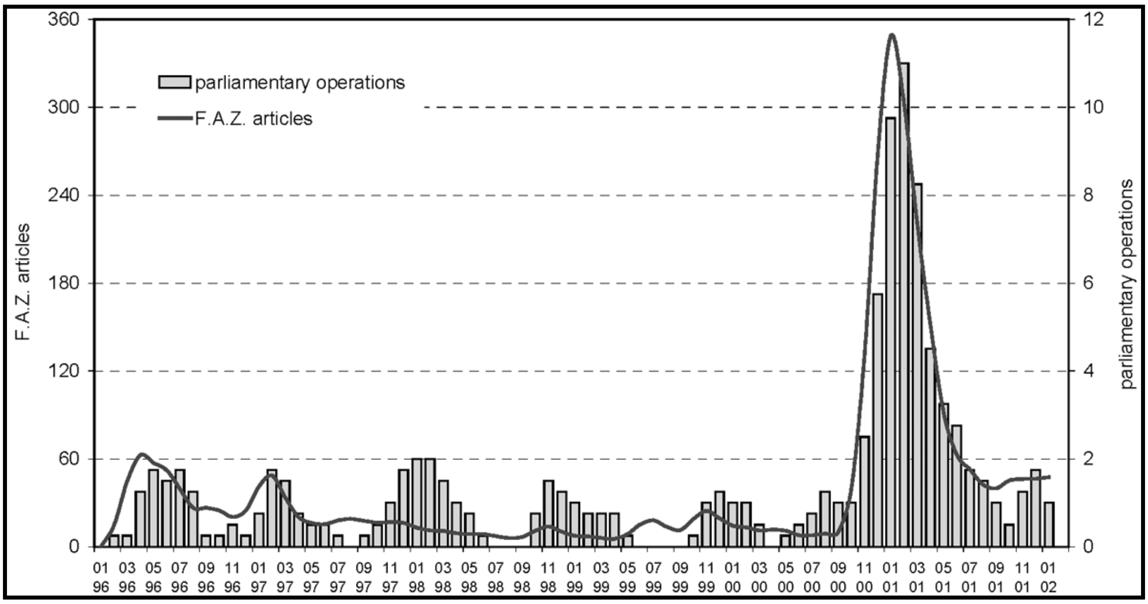
Issue-attention theory has usually employed a restricted number of (public and political) attention indicators, namely:

- The standard indicator for *public attention* to an issue is the *count number of newspaper articles* on the given issue (see e.g. Downs, 1972; Neuman, 1990; Mazur and Lee, 1993; McComas and Shanahan, 1999; Henry and Gordon, 2001; Newig, 2004; Liu *et al.*, 2011).
- The standard indicator for *political attention* to an issue is the *count number of parliamentary or congressional outputs* on the given issue (i.e. bill proposals, legislation, speeches, enquiries, hearings, reports etc.), usually published in governmental records (see e.g. Mazur and Lee, 1993; Bailey, 1998; Newig, 2004; Liu *et al.*, 2011).

Molitor (1977) identified several other indicators, not only for public attention (e.g. artistic outputs, or fiction/non-fiction books that mention a given issue) and political attention (e.g. political speeches and reports outside congress/parliament), but also for e.g. scientific and professional attention (e.g. scientific journals, trade journals, academic theses). As we saw (section II.4.2), the literature on technology hype-cycles also draw on indicators of (industry and other stakeholder's) attention to particular technologies, including: number of technological prototypes featuring a given technology (indicator of industry/firm attention used by Bakker (2010)); articles in specialized magazines about the technology (indicator of organizational-field/industry attention used by Bakker *et al.* (2012)); number of patents related to the technology (industry/firm attention used by Jun (2012)).

In issue-attention theory studies, these indicators are collected in regular intervals (e.g. monthly or annually) and plotted over time, revealing an overall pattern of peaks and valleys (the 'issue-attention cycle', see Figure II.7). For instance, Newig (2004) collected monthly data for public and political attention to BSE ('Bovine Spongiform Encephalopathy' aka 'mad cow disease') in Germany (Figure IV.1). However, the visual depiction of the time series data does not represent a crucial part of the methodology employed by those authors, who are mostly interested in testing issue-attention cycles as an agenda setting theory. They therefore draw on standard (or, sometimes, more sophisticated[45]) statistical methods to infer the relationship between public (media) and political attention. This is the approach adopted by Newig (2004); or by Jun (2012), who tests for causality between media, public and industry attention to vehicle technology.

Figure IV.1: Public and political attention to BSE in Germany



Source: Figure 8 in Newig (2004, p. 177).

In this thesis, however, the visual representation of time series data is part of the core – albeit preliminary – method of analysis. Here, I propose that *the visual representation of issue-attention data through time indicates distinctive periods in the overall issue life-cycle*. In other words, in my methodology, the visual representation of issue-attention indicators is a first attempt of 'temporal bracketing': of dividing the whole issue life-cycle into sub-periods. This division will allow me to structure the case study narrative in sub-periods, which I will later compare with the theoretical stages of the DILC-model (in the 'pattern-matching' exercise – see section IV.3.3).

[45] For example, Jun (2012) uses Granger Causality tests.

This kind of method is usually referred to as 'visual data mining' (Keim, 2002) or 'data visualization technique' (Marghescu, 2007), and aims at producing initial insights about broad patterns and apparent relationships between time series data. In the STI field, (sophisticated) 'visualization' techniques are used in scientometrics research (see e.g. Yang *et al.*, 2008; Rafols *et al.*, 2010; Leydesdorff *et al.*, 2012; Leydesdorff *et al.*, 2013; see also the Scientometrics journal). In this thesis, I will use simpler technique similar to the 'multiple line graphs' approach described by Marghescu (2007), in which the attention indicators are displayed in line, bar or area charts and synchronized by the use of same time intervals (see also Wainer, 1984, who shows what should be avoided when displaying quantitative data).

This *exploratory visual examination* I propose consists in establishing sub-periods in the data plots through the visual identification of e.g. periods between attention peaks or attention valleys (which are indicative of 'attention thresholds'), or periods of steady increase/decrease in attention, or periods of convergence of attention from different actors. However, I will not take the resulting periodization as final: to establish each case study's sub-periods, I will triangulate the visual examination with my knowledge of key events and processes during each issue life-cycle under analysis (and compare these with the 'phase shift processes' defined in Chapter III), in order to establish a more nuanced and objective periodization of each issue life-cycle. This is an attempt to address a caveat of this method, which is that it rests on subjective judgement. The appropriateness of this method to identify issue life-cycle stages shall be corroborated or overruled by the statistical tests for unknown structural breaks (see section IV.2.2.3).

Because this method presents little requirements and does not rest on strong statistical assumptions[46], it will be used in all three case studies (see section IV.3.1 for case selection). Yet, the number of attention indicators will depend on availability for each case. Here is a list of indicators used in one or more case studies:

- For public attention, I use the number of newspaper articles on the particular issue as proxy indicator.

[46] The only assumption (proposition) is that issue-attention indicators reflect developments in the issue life-cycle.

- For political attention, I employ two qualitatively distinct indicators: for policy-making activities *(*congressional attention) and policy-implementation activities (executive branch attention), respectively, I use issue-related entries in the *Congressional Record* and the *Federal Register*.[47]
- For organizational-field attention, I use as indicator the count number of articles in the *Automotive News* (American edition) on a given issue (to depict issue-attention cycles) and on different technologies (to depict technology hype-cycles).
- For industry and firm attention to a given technology, I use as indicator the count number of patents filed in the United States Patent and Trademark Office (USPTO).

While the use of attention indicators may provide important insights into the dynamics of an issue life-cycle, it is crucial not to take them 'at face value', and, as with any STI indicator, "they must be used with great care and in full awareness of their limitations" (Freeman and Soete, 2009, p. 584). Any indicator will capture only some aspects of the phenomenon it is related to and/or provide a 'blurred' insight into the phenomenon. Indicators may present problems of *definition* and of *measurement* (method). In the case of the indicators that I will use in this thesis, issues of the first type include the debate on whether newspaper coverage of a given issue reflects or is reflected by public attention. While I acknowledge this issue, studies (e.g. Liu *et al.*, 2011; Newig, 2004) have shown that media and public *co-evolve and reflect each other*, so that the use of media attention (count number of news paper articles on a given issue) as an indicator of public attention seems acceptable.

A measurement/method problem of attention indicators is related to their collection through a fixed set of keywords: the indicator does not account for changes in meanings, interpretations and framings of the issue. Moreover, this kind of indicator and data collection strategy does not account for changes in length of newspapers or articles (however, by using more than one newspaper as a

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[47] All case studies will focus on the US car industry (see section IV.3.1 for case selection). Therefore, here I am listing the indicators for political attention in the United States: the *Congressional Record* publishes transcripts of hearings, debates and speeches and bill proposals, indicating evolving attention to issues. The *Federal Register* publishes regulatory agency's notifications and rules and (presidential) executive orders, two key types of policy-implementation action at the US Federal level.

source, this issue is less of a concern). While a strategy could be devised to methodologically tackle the first issue (of meanings, interpretations, and framings), in this thesis I will tackle it through the narrative approach. However, I will carry out 'robustness checks' when collecting data on the attention indicators, by testing different sets of keywords to maximize the relevance of the results (indicators). In particular, the robustness checks will pay attention to the trade-off between inclusion of relevant articles and exclusion of irrelevant articles.[48]

Particular care should also be used when adopting *patents* as indicators of R&D outcomes, technologies, and innovation strategies. The STI literature on patents is well established and vast (see e.g. Pavitt, 1985; Basberg, 1987; Griliches, 1998; De Rassenfosse et al., 2013), and has identified many problems with the use of patents statistics as technology indicators; these include: differences in propensity to innovate between firms, sectors and countries; the content value (or quality) of different patents; the (often lack of) relationship between patenting a technology and commercializing it; the strategic use of patent portfolios (e.g. patents as barriers to entry). These can be regarded as definition problems. Patent statistics, if collected through keyword searches, can also be affected by similar problems as the attention indicators discussed above.

As will become clearer in each case study, in this thesis I will adopt different strategies to collect patent data, in order to minimize methodological issues (see discussion of case selection in section IV.3.1): in the air pollution case study, I will collect patents on emission control technologies based on keyword searches that include words related to the automobile industry (because these technologies are based on multiple scientific and technological fields, they are classified in multiple classes, sometimes unrelated to the car industry); in the car safety case study, I will collect patent data based on a class search in the US Patent and Trademark Office (due to limitations in the database, that prevents keyword searches for old patents, but also because car safety technologies are classified in well defined classes); and

[48] There are two key issues that affect the collection of articles based on keyword searches: the exclusion of relevant articles ('false negatives') and the inclusion of irrelevant articles ('false positives'). By modifying a search string to include more and more terms, one will reach a limit where more terms result in too many false positives, whilst it does not result in the inclusion of any (previously) false negative articles. To tackle these issues, one needs to try out different search strings and scan through the results to ascertain their relevance. This is a kind of robustness check that I will adopt.

in the climate change case study I will adopt a mixed strategy based on keywords and classes (based on the methodology of Oltra et al., 2008). In the climate change case, I will also look at patent portfolios of alternative-fuel vehicle technologies (the percentage of AFV patents in the total number of patents by each firm); this should minimize the issue with different propensities to innovate. While these strategies will not completely eliminate the problems with patent statistics that I flagged above, in all case studies, the narrative approach will help me minimize them, particularly the qualitative issues, like different propensities to innovate, commercialization of technologies, strategic use of patents, etc.

The case studies will also draw on non-attention indicators such as product sales (technology diffusion indicators), firms' financial results, governmental funding for technology R&D, market-shares (of companies and technologies), and others. Each case study (chapters V to VII) will detail the data used for the quantification method (see case study protocol).

IV.2.2.2. Meta-analysis of correlations within a temporal bracketing framework

A second quantification method to be employed in this thesis is to calculate correlation coefficients between paired time series, e.g. between political and public attention; or between industry (patenting) attention and regulatory attention. These correlations can be calculated for the overall period of interest (the whole issue life-cycle) and sub-periods (e.g. correlations before and after an identified 'turning point' in the issue life-cycle). The resulting set of correlations for each paired time series in the whole and sub-periods can be compared through a meta-analysis based on well-established statistical procedures (Kenny, 1987; Walker, 2003).

In this thesis, I use a statistical test to verify the significance of the difference between two independent correlation coefficients (e.g. to test whether correlations between political and public attention is equal before and after a 'turning point', or to test whether industry attention is more correlated with public or political attention) (Kenny, 1987).[49] Because the proxy variables are not normally distributed, as required for the calculation of Pearson's correlation coefficient, this

[49] The test takes into account sample sizes for each period. I assume correlation independence in different periods due to 'structural breaks' in the series (visually, statistically or qualitatively identified), i.e. a given event leads the series to behave different before and after a turning point.

meta-analysis will be based on the Spearman's rho correlation coefficient, which is more appropriate for non-parametric/non-normally distributed data and for small-sized samples (Gibbons and Chakraborti, 2003). Because I will use Spearman's rho, when performing the statistical test, I have to transform Spearman's rho into an equivalent value of Pearson's r (Gilpin, 1993), and perform the so-called 'Fisher transformation' of the latter (Kenny, 1987).

As I will be using a non-parametric statistic, this method does not require strong assumptions about the distribution of the data (e.g. that the data is normally distributed). It does however require availability of appropriately sized series of attention indicators; hence, this represents one technical criterion for case selection (see section IV.3.1). Moreover, it requires 'good quality' data, in the sense that I will assume that a quantitative indicator represents qualitative aspects of an issue life-cycle. If successful, this analysis can offer important insights into within-phase relationships. Yet, because correlation does not imply causality[50], these insights shall be further explored through an in-depth narrative method.

IV.2.2.3. Testing for unknown 'structural breaks' in the time series

In time series statistics, a so-called 'structural break' occurs when the implicit population function changes over the course of the sample under consideration (Stock and Watson, 2006). A classical example of a break in economic time series data is a peak in unemployment following the outbreak of a financial crisis. In terms of attention data indicators, a structural break can be hypothesized to also happen after 'trigger events' (such as a 'financial crisis' in the unemployment example): before the event, attention would be fluctuating around an average level; after the event, attention would start to increase fast. Structural breaks can also happen after attention reaches certain levels, and then decreases fast.

There are two main methods (statistical tests) for detecting such breaks from time series data[51], both of which are usually employed in macro- and financial economics analysis. In one method (the 'Chow Test'), the break date (in the same

[50] Spearman's rho correlation coefficient can be interpreted as a generic measure of association (Noether, 1981). Its calculation is based on the ranking order of sample values: let's say two samples of interest (e.g. political and public attention) consist of ten yearly observations each. The procedure is based on attributing a rank order (1st-10th) to the values according to their size and calculating the correlation between rankings. An interpretation for a high correlation coefficient, in this example, would be: high/low level of public attention in one year is associated with high/low level of political attention in this same year.

[51] The visual analysis method outlined above is an attempt to *visually* identify such breaks.

unit of time as the data has been collected, e.g. month, quarter or year) is known (or hypothesized) in advance (Torres-Reyna, 2013). The second method is a modified Chow Test, called the *Quandt Likelihood Ratio* (QLR) test (after Quandt, 1960), which tests for *unknown break dates*. "The QLR test can detect a single discrete break, multiple discrete breaks, and/or slow evolution of the regression function" (Stock and Watson, 2006, p. 569).

The QLR test therefore seems appropriate for *a-priori* analysis of attention indicators, in order to establish sub-periods (or temporal bracketing in phases) through the use of statistics.[52] To get a more precise picture, I will compare the results from the QLR tests with the visual examination of the plotted time series and my initial knowledge of key events in the issue life-cycle. This shall also reveal the appropriateness or otherwise of the visual examination of time series as a method for identification of stages. Given the exploratory nature of this thesis' methodology, I will restrict the use of this more sophisticated method to the contemporary case (see next section), which offers richer sources of data (attention indicators) for a relatively long period.

IV.3. CASE SELECTION, CASE STUDY PROTOCOL, PATTERN MATCHING AND CROSS-CASE COMPARISON

As explained in section IV.2, the narrative and quantification strategies are part of a case study approach to test the DILC-model against empirical examples of issue life-cycles. Case studies are an adequate research strategy "[1] when 'how' or 'why' questions are being posed, [2] when the investigator has little control over events, and [3] when the focus is on contemporary [but also historical] phenomenon within some real-life context" (Yin, 2003, p. 1). Moreover, case studies are suitable for understanding complex causal mechanisms (George and Bennett, 2005), being therefore appropriate for the proposed research. This section will explain key

[52] The test rests on the assumption that the model errors (estimated by the QLR test) are independent and identically distributed, and this will be tested in this research. The reader is referred to Stock and Watson (2006, p. 567-571) for the technical description of the statistical test. In this thesis, I will use the modified procedure (based on Stock's and Watson's) explained in Torres-Reyna (2013), who also makes available a 'do-file' for running the test in STATA. As I will be using annual data, my tests will include up to four lags (five restrictions) to account for autocorrelations and distal breaks (due to e.g. election cycles); the tests will be applied to the natural logarithm of the variables. All statistics' procedures in this thesis will be performed in Stata 12.

factors in case study design: the case selection, the case study protocol, and the method of analysis (pattern-matching and cross-case comparison).

IV.3.1. Case selection

A common criticism to case studies is that they would not allow for generalizations and, therefore, would not be able to contribute to 'scientific' development. Flyvbjerg (2006) has convincingly argued that this criticism is incorrect, because generalization "depend on the case one is speaking" (p. 225). Therefore, *case selection* is crucial for theory development: instead of 'random sampling' (as used e.g. to test variance theories that aim at uniformity across cases), in case studies, selection is purposively undertaken based on the potential information content of the cases.

> *Case-selection decisions stem from the research hypothesis. Specifically, each case should serve a unique purpose within the overall scope of enquiry. Each case must be chosen to complement others, e.g. because theoretically interesting patterns are expected.* (Johnston *et al.*, 1999, p. 206)

In other words, in case study research, cases should be selected due to theoretical or methodological reasons (Yin, 2003). In light of this thesis' research purposes, the main theoretical criterion for selecting cases is that they must involve *the development of technologies by an incumbent industry in response to a societal issue*. Moreover, the thesis aims at contributing to the 'Grand Societal Challenges' agenda, and therefore the issues studied should indeed represent societal challenges. On top of these my theoretical framework – the DILC-model – also informs case selection:

- Cases should span many decades, in order to be able to investigate the processes in full, from issue emergence to resolution (or otherwise). Therefore, *historical case(s) shall be included in the case sample*.
- The DILC-model identifies two processes (or routes) for industry recreation: through *changes in consumer preferences* and *enactment of strict regulation* (e.g. technology-forcing policies). Therefore, *two* historical cases should be selected, each revealing at least one of the processes.

- Lessons from historical case(s) should be relevant for the contemporary agenda of 'Great Societal Challenges'. Therefore, the DILC-model shall be further tested with a *contemporary* case.

In previous chapters, I have also outlined other case selection criteria:

- At least one of the cases should include technology hype-cycle(s) throughout the issue life-cycle;
- Cases should allow the application and testing of the novel methodology: (a) data series of attention indicators should be available for all cases, in order to allow for the use of the exploratory visual examination method; (b) sufficiently long time series for attention indicators should be available for at least one case, so that the meta-analysis of correlations can be applied; (c) at least one case should have 'good quality' attention indicators for a sufficiently long period, in order to allow for the use of both the correlation analysis and the QLR test.
- Moreover, my selection of cases shall also take into account that the DILC-model represents the 'normal' pathway of an issue life-cycle, i.e. the standard sequence of phases, from 1 to 5. It is therefore important to select at least one case that seems to deviated from this pattern.

These research-specific criteria result in a three-case sample: two historical cases and one contemporary. These cases shall cover the response of incumbent industries to problems that represent(ed) societal challenges. My case selection choices operate at two levels: the choice of industry or industries to be analysed, and the choices of cases (issues) affecting this industry. Which industry(ies) shall be chosen? Flyvbjerg (2006) suggests four (non-mutually exclusive) generic strategies for selecting cases, which I will apply to select the industry on which I will focus: selecting (a) *extreme or deviant cases*; (b) *maximum variation cases*; (c) *critical cases*; or (d) *paradigmatic cases*. An extreme case is one that is unusual or clearly ('extremely') illustrates the theory being tested. A maximum variation case strategy aims at choosing two opposing cases in one dimension, holding constant another dimension. A critical case is the one that has crucial importance in relation to the topic under study and allows for inferences of the kind 'If this is (not) valid for this case, then it applies to all (no) cases': it is a 'least likely' or 'most likely' case. Finally, the paradigmatic case is the one that represents an 'exemplar' for the phenomenon under study and so develops a new metaphor or a new theoretical line of enquire.

Regarding the first choice, I will aim at choosing an industry that can be regarded as *extreme* case: the American automobile industry, which has been historically and contemporarily associated with many societal issues. Amongst those issues are (Parry *et al.*, 2007): local air pollution; global air pollution ('climate change'); oil dependency; traffic congestion; and traffic accidents ('car safety') – all of which can be regarded as 'societal challenges' on their own[53]. Because of (a) the scope of the issues associated with it (spawning the whole country) and (b) the confrontational approach towards institutional demands (Luger, 2000), the *American* automobile industry's response to societal issues also represents an *extreme case*. Analysing this industry can thus potentially "reveal more information because they activate more actors and more basic mechanisms in the situation studied" (Flyvbjerg, 2006, p. 229). Furthermore, the analysis of the automobile industry's strategic response to issue-related pressures attends practical concerns, because this industry is still associated with present-day Grand Societal Challenges, such as climate change.

One issue when selecting extreme cases is generalization: they can be so unusual, that the analysis results in biased conclusions, distorting the portrayal of the phenomenon under analysis (Verhees, 2011). Instead of aiming at complete 'versatility across cases', I will aim at middle-range generalizations (see section IV.4).

Choosing one single context (the USA) also presents practical and analytical benefits. Given the historical importance of the American automobile industry, a vast amount of primary and secondary data sources is available. By studying this single industry, I can draw on these sources for a detailed analysis of the cases through triangulation of evidence. This also allows me to accumulate knowledge about the industry throughout this thesis' research enterprise. Moreover, amongst

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[53] Whether they represent 'Grand' challenges can be debated. Yet, they are all *persistent* problems that pose formidable challenges to societies, and present characteristics similar to new challenges (or 'missions') as outlined by Soete and Arundel (1993), such as the need for complementary policies, and direction of change (solutions) influenced by many stakeholders, competition between old and new technologies. In any case, my position is that the way the automobile industry responded to those challenges can provide invaluable lessons as to how to deal with 'Grand' Societal Challenges.

data readily available are attention indicators, which are crucial for testing my proposed methodology.

On the downside, choosing the American car industry has limitations (Geels and Penna, 2013) associated with geographical boundaries and the globalization process: (1) foreign-owned automakers operate and produce in the US market; (2) American car companies operate abroad. These limitations will be addressed with a research protocol (see next section) that includes the discussion of (a) foreign carmakers' strategies as (economic) pressures on the American industry; and (b) global developments (e.g. other national and global policies) as (institutional) pressures on the American car industry.

So, given that the American car industry has been associated with multiple issues, which one shall I select for my analysis? This second choice will be informed by the criteria outlined above. The historical issues I chose are *local air pollution* and *car safety*. These issues meet the criteria of representing societal challenges, and they have a long history of developments, so that they can potentially reveal insights about all phases of the issue life-cycle. Moreover, they meet the variation criteria: on the one hand, local air pollution lead to partial regime reorientation (changes in the technical regime) through technology-forcing regulation (the Clean Air Act, which resulted in catalytic converters being brought to markets); on the other hand, car safety became an important factor in consumer's preferences, so that regime reorientation around car safety can be seen as having followed the 'changes in consumer preferences' route. The contemporary issue I choose is climate change, because it represents a key – if not the foremost – Grand Societal Challenge of our time. It also meets the 'technology hype-cycle' criteria, as many technologies (e.g. electric vehicles; biofuels; hydrogen fuel-cell etc.) have received hypes of attention as 'solutions' to the car industry's contribution to climate change.

These cases also appear to differ on one important aspect: an initial assessment of these case stories and attention indicators (see below) seem to indicate that local air pollution followed a 'normal' issue life-cycle; car safety appears to have followed a more complex life-cycle on the problem side; while climate change seems to be following a complex life-cycle both on the problem and solution sides – the latter two cases are therefore expected to deviate from the standard sequence of phases posited by the DILC-model.[54] Altogether, these three cases meet the 'maximum variation' criteria and shall allow me to assess the versatility of the DILC-model and to improve it according to empirical findings. The three cases also allow for the application of my novel methodology. There is an array of attention indicators available for all three issues; the safety case is particularly long for testing the meta-analysis of correlations method; and the contemporary case present rich and sufficiently long data series, which allows for the application of both the correlation analysis and the structural break testing method. Here I present a summary of the three cases to be studied for testing and elaborating the DILC-model:

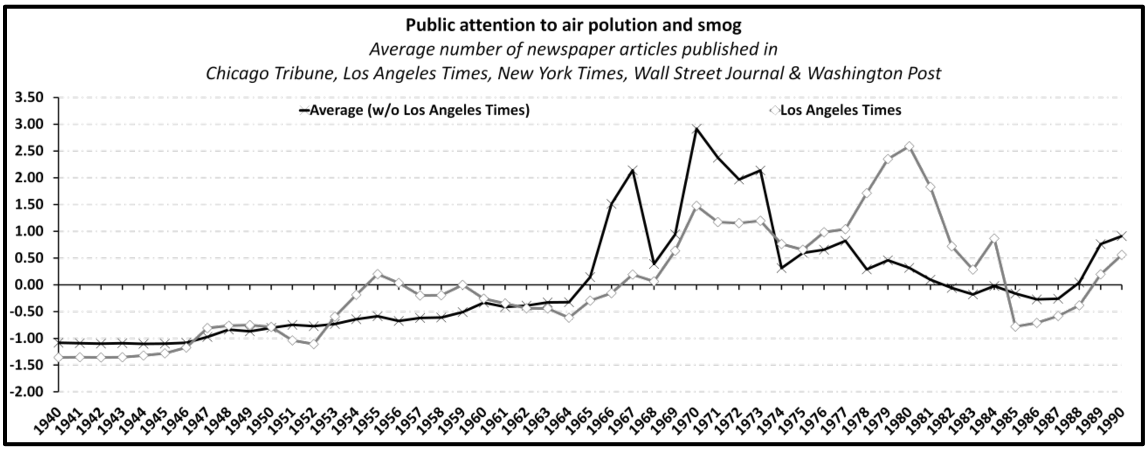
1) *The issue of local air pollution and the American automobile industry (1940s-1980s).* This is a well-documented case[55] that seems to follow a trajectory very close to the normal path: in the 1940s, social groups voiced concerns about an unusual 'smog' in Los Angeles, and the issue life-cycle began. In the early fifties the issue was framed as caused mostly by cars (and some stationary sources). The car industry acknowledged the problem and promised solutions (mostly incremental). In the 1960s, the environmental movement, which emerged the decade before, succeeded in influencing public opinion, and soon politicians joined the debate. The process culminated in the *Clean Air Act of 1970*, which restricted emissions from new light-duty vehicles and forced the adoption of improved emission-control technologies (i.e. catalytic converters) that could meet these restrictive standards. A complicated implementation process began. In the early 1980s, three-way catalytic converters became mandatory technology in new automobiles sold in the US. Figure IV.2 shows how public attention to air pollution fluctuated in the US from 1940 to 1990 (note that

[54] These differences may be related to the 'size' (or scope) of these challenges, with climate change being the classic example of 'Grand' Societal Challenge, and therefore requiring more complicated changes than safety and air pollution (in principle, the simplest issue in terms of technological fix). While these hypothesized differences are not criteria for case selection, they also contribute to testing the versatility of the DILC-model.

[55] Although many authors have investigated this case (e.g. Krier & Ursin, 1977; Doyle, 2000; Luger, 2000; Lee *et al.*, 2010; Gerard and Lave, 2005), their analysis tells only part of the story, e.g. either focusing on policy processes or the effects of regulations on innovative activities, or covering just part of the issue life-cycle (usually the implementation stage).

attention in California, indicated by articles published in the *Los Angeles Times*, presented a different dynamics): the shape of the curve – with a peak in 1970 – is another indicator that the air pollution issue life-cycle followed a path similar to the hypothesized by the DILC-model. By the mid-1980s, attention to air pollution decreased to pre-1965 levels, only starting to increase again in 1987 (1986 in California), but in connection to new environmental issues such as acid rain, which resulted in a revision of the *Clean Air Act* in 1990[56] (a complete visual analysis of this and other attention indicators will be exposed in the empirical chapter).

Figure IV.2: The air pollution public attention cycle in the United States



Source: Author's construction (methodology to be detailed in the empirical chapter).

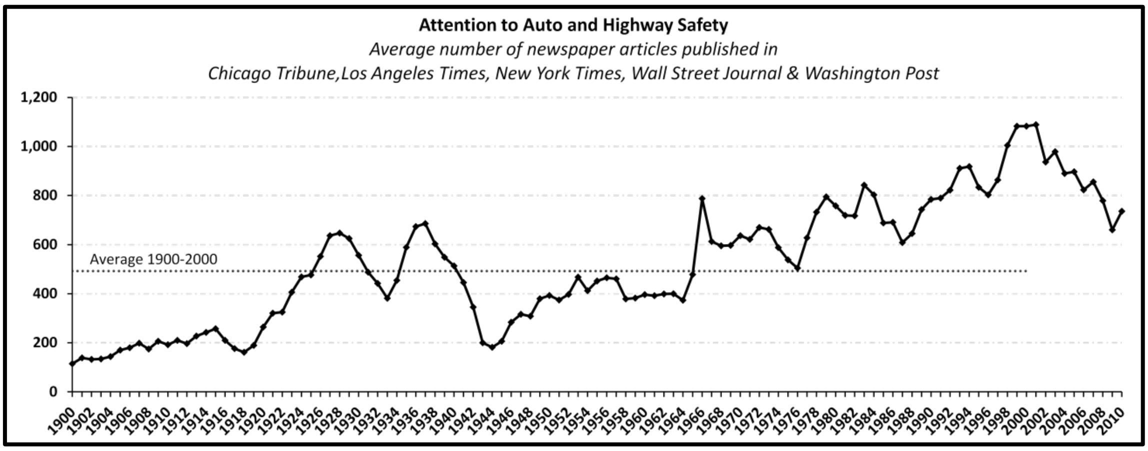
Obs.: The chart shows the standardized values of the yearly average of count numbers of articles on air pollution published in the four newspapers: negative values indicate years when the number of articles stayed below the average for the whole period (1940-1990), positive values indicate years when number of articles were above the whole period average.

2) *The issue of automobile safety and the American automobile industry (1900-2000).* This issue represents an important and *long* challenge for the American society, and I expect all DILC-model phases to be present in this case – albeit the chart of public attention to car safety in the US (Figure IV.3) indicates escalating attention: the issue life-cycle likely did not follow a 'normal' path. It emerged slowly, together with the diffusion of cars. Early on (1916) it received a behavioural framing – 'road safety' was framed as a triple 'E' (*3E's*) problem: driver *E*ducation; road *E*ngineering; and law *E*nforcement (Luger, 2000) – the car itself was not part of the equation. The industry therefore was happy to embrace the 3E's. In the 1930s, some individual activists began to advocate a

[56] In the case study (Chapter V), I explain the rationale for stopping the analysis in the 1980s.

technological framing. Yet, with the outbreak of Second World War, the issue life-cycle was apparently interrupted. Only in the 1950s, with the continuous increase in the number of road fatalities, the issue re-emerged in the institutional environment, leading to framing struggles between defendants of the behavioural framing and those who defended the technological one. In 1966, a strong piece of legislation was enacted by Congress, which adopted the technological framing.[57] Notwithstanding, implementation was long and complicated, and, in the 1980s, safety innovations were mainly incorporated in cars not as a result of policy, but of consumer demand.

Figure IV.3: The car safety public attention cycle in the United States

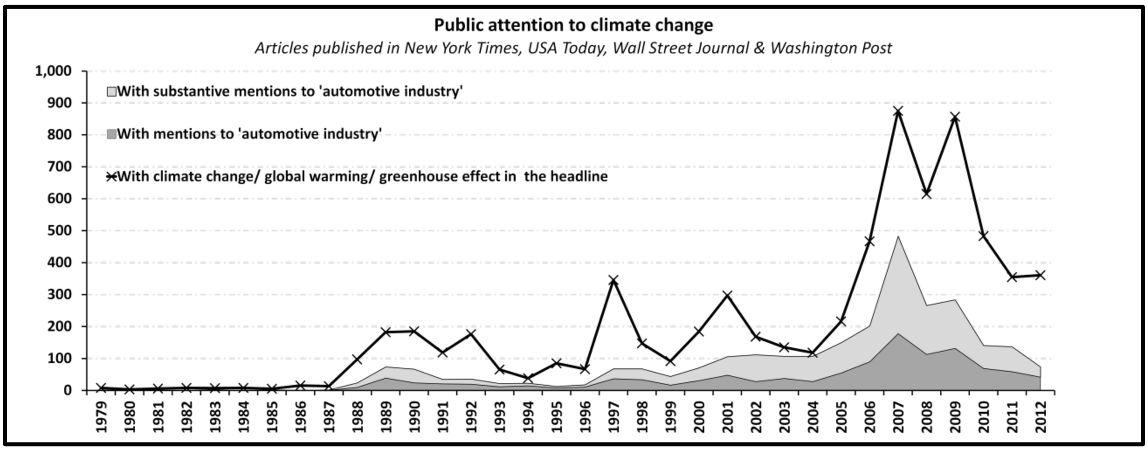


Source: Author's construction (methodology to be detailed in the empirical chapter).

3) *The issue of climate change and the American automobile industry (1979-2012).* The science behind global warming/climate change has a long history. But it is in late 1980s that it became a public concern in the US, through the action of activists and already institutionalized pressure groups. As shown in Figure IV.4, the automobile industry has always been implicated in the issue, and increasingly so since the 2000s. As this is a contemporary issue, the case study will seek to establish at which stage in the Dialectic Issue Life-Cycle is climate change, regarding the American auto industry. With the help of insights from the previous cases, I will also seek to indicate what can be expected in this issue life-cycle in the medium-run.

[57] The possibility of an issue changing meaning ('framing') has not been incorporated in the DILC-model. This is an important aspect of the safety case, which I believe can provide important insights for developing the model.

Figure IV.4: The climate change public attention cycle in the United States



Source: Author's construction (methodology to be detailed in the empirical chapter).

Because those issues partly run concomitantly during their life-cycles, the cases studies will likely bring about insights into how these issues affected each other in terms of pressures (e.g. do they reinforce or undermine each other?) and industry response (e.g. does the industry play out on trade-offs between the issues?).

Building on Tushman and Romanelli (1985), the three cases can also be categorized in light of their differences in terms of which kind of changes were/are required in the industry regime to address the issue. While air pollution can be seen as the easiest problem to be addressed within the bounds of the prevailing regime (i.e. the 'solution' only required the development of emission control technologies, which are add-on innovations and can be conceptualized as incremental change from a technological regime point of view), safety already entailed changes in more elements of the regime (e.g. it also required a shift in the industry's 'mindset', because of the overall belief that 'safety doesn't sell, big cars sell' – therefore, it required 'strategic reorientation'). Climate change appears to be the most challenging issue, because it may require the 'recreation' of the car industry: changes in the four core elements of the regime. These differences highlight how the case sample adheres to a maximum variation rationale also in terms of outcome, which can potentially provide further insights to improve the DILC-model.

IV.3.2. Case study protocol

The case study protocol (or plan) "stipulates what information is to be sought to fully investigate the research hypothesis and how it is to be obtained" (Johnston *et al.*, 1999, p. 207). It usually includes a set of questions or topics (Geels, 2002) that guide the case study investigation, which can be labelled as 'working questions' (as opposed to the core 'research questions'). Part of the protocol is to specify data sources used in the case study, and "in every case, evidence from multiple sources must be collected in order to allow for triangulation" (Johnston *et al.*, 1999, p. 207). I here specify the case study protocol, which is based on the DILC-model conceptualization. This protocol represents the structure that I will follow in the empirical chapters (V-VII):

1) *Introduction:* the introduction to each empirical chapter explains particularities of the case that may result in important insights for this thesis' research focus. It also explains particular roles the case play in the development of the DILC-model.
2) *Data sources:* the second section of each empirical chapter will present primary and secondary data sources for the quantitative and qualitative data, including the description of data collection procedures in the case of attention indicators.
3) *Quantification approach – attention dynamics:* the third section will apply the quantitative method(s) to the case (according to the quality and availability of data). This quantification approach will result in a first sub-periodization of the overall period of interest, which will be triangulated with my qualitative knowledge of key events. The quantification approach may reveal first insights about mechanisms and dynamic interactions, which will be further explored in the qualitative (narrative) approach.
4) *Qualitative approach – in-depth narrative:* The fourth part of each empirical case study will consist of an in-depth narrative aimed at identifying deeper causal mechanisms though analysis of the interactions and processes in the institutional and task environments. This longitudinal case narrative will be divided in the sub-periods resulting from point (2) above. Each sub-period will be further divided into[58]:

[58] This subdivision reflects the linearity of every narrative (Geels, 2002). However, the DILC-model highlights the multidimensionality and *dialectics* of the issue life-cycle process, so that at times and where warranted references to e.g. response strategies will be presented under a 'pressure' heading.

a. *Pressures around the issue:* which institutional and economic pressures connected to the focal issue were present in the period? Depending on which pressures were present, a sub-period may contain reference to *socio-cultural pressures*; and/or *political pressures*; and/or pressures from *consumers*, *suppliers* and other *regime outsiders* (including foreign manufacturers) etc.

b. *Incumbent industry issue responses*: what were the strategies deployed by the incumbent industry in response to issue-related pressures? Depending on which strategies were deployed[59], a sub-period may contain reference to *socio-cultural strategies*; and/or *political strategies*; and/or *economic positioning strategies*; and/or *innovation strategies*.

c. *Influences of broader industry contexts on issue life-cycle:* which other non-issue-related factors were present in the period and influenced the issue life-cycle? This working question seeks to identify interactions with broader industry contexts (i.e. other strategic issues faced by the industry, like shrinking profits) and external developments (such as the outbreak of an economic recession or a war), which is an aspect not conceptually incorporated in the DILC-model.

5) *Analysis*: Each case study will end with a pattern-matching analysis (see next section) between the empirical study and the DILC-model, which aim at answering the question: has the case followed the hypothesized DILC-model phases? If not, what were the major deviations? How can

[59] The notion of 'strategy' that I adopt throughout this thesis is based on a *post hoc* assessment of what firms and the industry actually did, and not on their *ex ante* 'strategic plan' (supposing they existed). However, in the narrative, I do take note of what firms and the industry declared to be their strategy and discuss it in light of what they in fact did (based on the observed strategies as reported in secondary accounts that present primary material such as interviews with key decision-makers). In this sense, to carry out the analysis, I do not explicitly partake in any single schools of strategic management; yet, in my view, strategy formation is less of a rational strategic planning or designing process than it is a process of cognition, learning, positioning, and negotiating that depends on internal and external institutions (see Mintzberg et al., 2009). Therefore, in line with my ontological and epistemological assumptions, I see strategies as an *emergent process* that enacts and reacts to internal/external developments, and that change overtime. While a key caveat of adopting a *post hoc* view on strategies is that the assessment is based on a subjective analysis, I attempt to minimize this issue by drawing on multiple sources and by triangulating evidences.

these be explained? The analysis section also includes an 'explanation building' (Yin, 2003) exercise, which will look at the particularities of the case (outlined in its introductory section).

6) *Concluding remarks*: The concluding section shall address and discuss how suitable and compatible (with the narrative explanation) were the quantitative method(s) employed in case. It will also draw implications for this thesis' research focus and questions

IV.3.3. Analytical strategies: Pattern-matching, explanation building and cross-case comparison

IV.3.3.1. Pattern-matching and explanation building

Yin (2003, p. 116) suggests that in case study analysis, "one of the most desirable techniques is using a pattern-matching logic [...] [which] compares an empirically based pattern with a predicted one... If the pattern coincides, the results can help a case study to strengthen its *internal validity*." Pattern-matching consists in accessing whether the empirical case study has a 'good fit' (Geels, 2002) with the DILC-model. In the analysis, I will also triangulate and discuss the results from pattern-matching with the quantitative results.

I regard the DILC-model as an ideal-type, which highlights certain (relevant) aspects that characterize the phenomenon of interest and differentiate it from others. An ideal-type therefore does not encompass all possibilities, characteristics and factors that affect a given phenomenon, in the case, issue-life cycles. Empirical cases are richer and more complex than the ideal type, so that deviations are beforehand expected. However, the analyst should strive to explain the deviations with resource to conceptualizations from the model. In case this is achieved, the *internal validity* of the model is maintained.

Deviations between the empirical case and theory will be further looked upon through an 'explanation building'[60] exercise (Yin, 2003), which will seek to draw implications to the DILC-model. The goal here is not to further check the internal validity of the model, but to develop new propositions to improve the model. Each case study will thus result in specific lessons and insights that will be

[60] Note that the case study narrative is an explanation building exercise in itself.

compared and, if possible, combined, in order to help addressing the thesis' research questions and gaps in existing literatures.

IV.3.3.2. Cross-case comparison

This thesis adopts a multiple-case design (Yin, 2003), which is usually regarded as more robust than single case studies, for it tends to result in more compelling evidence for confirmation or rejection of theoretical constructs. In the multiple-case design, with each case serving a specific purpose in the research effort, "*a major insight is to consider multiple cases as one would consider multiple experiments* – that is, to follow a 'replication' logic" (Yin, 2003, p. 47 – *original emphasis*). Replication depends on case selection based on specific theoretical criteria, so that each case study shall reveal particular patterns and mechanisms. Thus, from the replication approach follows a cross-case comparison exercise, i.e. the analysis and comparison of results from the multiple cases. As Turnheim (2012) suggests, comparing explanatory narratives of the multiple case studies is akin to Weick's argument about the comparison of events: "what any event means, what is significant in its unfolding, may become clearer when it is compared with another event, and the observer looks for similarities and differences" (Weick, 2007, p. 17, *apud* Turnheim, 2012).

This cross-case analysis is similar to the explanation building exercise, but it draws on the comparison of multiple cases and of these with the DILC-model. In summary, the comparison of cases allows the researcher to identify whether certain patterns or mechanisms depend on idiosyncrasies or whether they may be generalized. This cross-case comparison analysis will be carried out in the concluding Chapter (VIII).

IV.4. CONCLUDING REMARKS

This chapter has outlined the methodology based on which the DILC-model will be applied and tested against empirical cases. If successful, the mixed-methods methodology can represent an original contribution of this thesis. Yet, because I adopt a *case study* methodology, a question that may arise is: how versatile ('generalizable') will the findings be?

Even when a case is carefully and strategically chosen, generalizations drawn from it can be criticized for being contingent on particular types of cases.

This is why ‘middle-range theory’ development is a more feasible goal than broad generalization when building theory from case studies. Middle-range (typological) theories “identify recurring conjunctions of mechanisms and provide hypotheses on the pathways through which they produce results, provide more contingent and specific generalizations for policy-makers and allow researchers to contribute to more nuanced theories” (George and Bennett 2005, p. 8).

In this thesis, I will aim at middle-range theorization, so that generalization out of my research may be limited to industries that present similar characteristics to the automobile industry. This industry is (a) economically big and concentrated on few large firms (oligopoly); (b) politically powerful; and (c) culturally visible. Moreover, (d) the industry supplies differentiated products (‘innovations’) directly to the final consumer. Some industries that match these criteria to a great extent are: food industry; pharmaceuticals; ICT industry (especially computer and mobile hardware, but increasingly the Internet industry). Although utilities and integrated oil companies do not fully match the fourth criteria (e.g. their products are almost undifferentiated), I expect the DILC-model to be versatile enough to be applied to cases in these industries.

V. LOCAL AIR POLLUTION AND THE AMERICAN AUTOMOBILE INDUSTRY (1940S-1980S)

V.1. INTRODUCTION

This first case study[61] aims at testing the overall specification of the DILC-model by applying it to a well-documented case: the issue of local air pollution and the responses from the American car industry, from the 1940s to the 1980s. Although many authors have studied the case, they did so from a limited point of view, either not looking at the whole period or taking a disciplinary approach (see the discussion of secondary sources in section V.2.2). Many previous studies (e.g. Gerard and Lave, 2005; Nill and Tiessen, 2005; Lee *et al.*, 2010) start their analysis in 1970, when strict *Clean Air Act* amendments were enacted. By beginning in 1940, instead, I am able to address struggles over the definition of the air pollution issue (and thus its emergence), the mobilization of activists and social groups ('attention advocacy'), and early industry strategies.

Moreover, the existence of many disciplinary studies about the American car industry (on air pollution, but also on other strategic issues) also allows me to triangulate sources and build a comprehensive picture for a multi-dimensional analysis that addresses one shortcoming of empirical issue life-cycle and indeed greening of industry studies: the strict emphasis on the 'focal' issue (Mahon and Waddock, 1992; Bigelow *et al.*, 1993; Schaefer and Harvey, 1998). With the aid of the DILC-model and the TEF conceptualization, I will investigate how other strategic issues interfered (or not) with the local air pollution issue life-cycle.[62]

Thirdly, although the innovation that was framed as a solution to car emissions (the catalytic converter) was an 'end-of-pipe' technology, it was not a simple (incremental) 'add-on innovation': my case study will show that the development of the more advanced 'three-way catalytic converter' required acquisition of external (chemical and eletronic) competencies and entailed further reconfigurations of engine technology that amounted to costly architectural

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[61] A shorter version of this case study appears in Penna and Geels (2012). While I use part of the material in this Chapter, the present case study differs and goes beyond the published case study. Firstly, it draws on more sources and highlights additional evidence for the analysis. Secondly, due to a more specific quantification (visual analysis) approach, my periodization here differs slightly from Penna and Geels (using 1963 instead of 1960 as a breaking point). Finally, I include in the analysis developments up to 1990 (instead of ending the discussion in 1985).

[62] I shall return to this point in the analysis section.

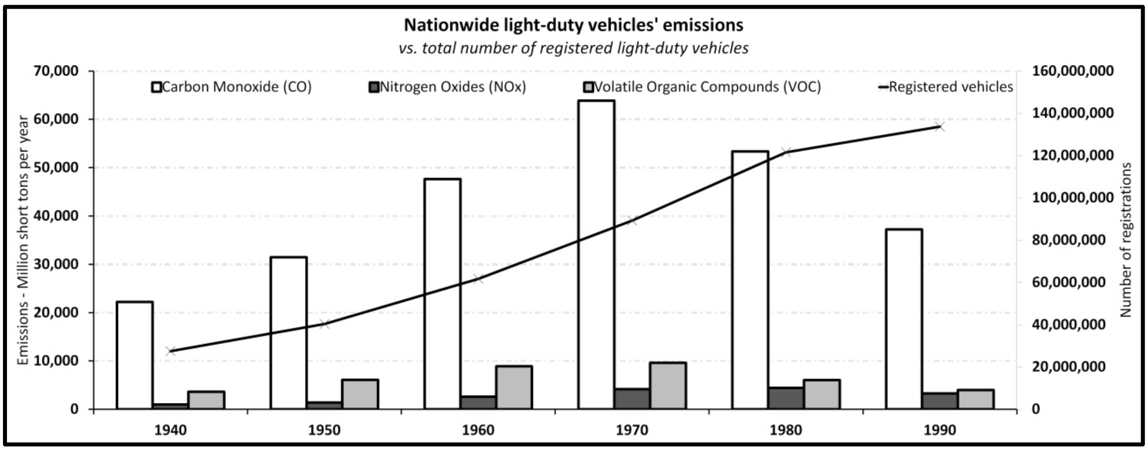
change (Henderson and Clark, 1990). This resulted in tensions and defensive strategies by automobile makers. The case study thus investigates and reveals the sources of this industry inertia and resistance.

Fourthly, several studies from the technology-forcing policy literature are centred on this case (Yao, 1988; Leone, 1999; Gerard and Lave, 2005; Gerard and Lave, 2007; Lee *et al.*, 2010; Tao *et al.*, 2010; Lee *et al.*, 2011). Indeed, the American automobile industry reoriented and innovated with the catalytic converter to address local air pollution because of policy: the issue life-cycle followed the 'changes via regulation' route. My approach will allow me to investigate why and how the issue life-cycle resulted in the adoption of this route. I will also investigate whether the 50-year-long process was accompanied with changes in other regime elements, besides industry specific regulations (i.e. the industry's identity and mission and/or its belief system). [63]

I end the case study in the 1980s (1990) for three reasons: firstly, because, as shown in the public attention chart (Figure IV.2), in the 1980s, attention to air pollution ('LA-type smog' [64]) went to pre-1965 levels. [65] By then, automobile emissions of pollutant gases that form LA-type smog (henceforth referred to simply as 'smog') had been reduced to pre-1960s levels (with the exception of NO_x), despite the constant increase in the number of vehicles registered in the US (see Figure V.1). By 1990, virtually all cars in circulation had emission control systems, most of which (88%) included a catalytic converter (see Figure V.2).

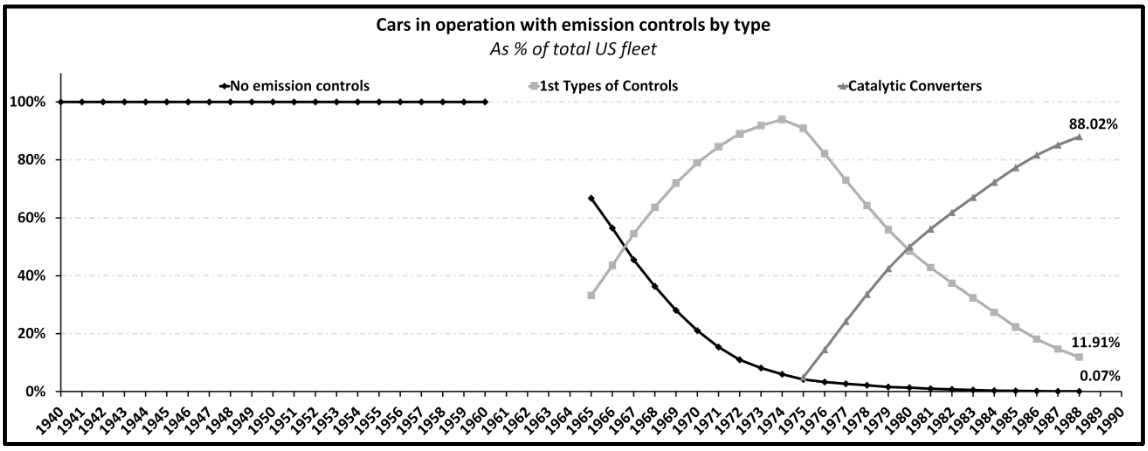
[63] The third and fourth points will also be tackled in the analysis section.
[64] The Los Angeles type of 'smog' differs from smog that results from smoke and fumes produced by industries, power plants, refuse burning and household heating systems. This latter 'London-type smog' is formed by suspended carbon particulates and sulphur dioxide. While "[t]he automobile contributes very little to this particular type of air pollution" (Mondt, 2000, p. 8), it is the major source of air pollutants that result in LA-type smog: oxides of nitrogen (NOx), unburned hydrocarbons (HC), and volatile organic compounds (VOCs), which in the presence of sunlight reacts into ozone (O_3).
[65] Attention to 'air pollution' started to increase again in 1988, but in connection to new environmental issues such as acid rain (Dunlap and Mertig, 1992), which resulted in a revision of the Clean Air Act in 1990.

Figure V.1: Emissions from light-duty vehicles in the United States, 1940-1990



Source: Author's construction based on data from USDT Federal Highway Administration (registrations) and USEPA (emissions)

Figure V.2: Diffusion of light-duty vehicle emission control technologies in the US, 1940-1988



Source: Author's construction based on data from *Ward's Automotive Yearbook* (several issues).

Obs.: Missing values between 1964 and 1988 (1966, 1968-70, 1973-4, 1985, and 1987) were interpolated.

V.2. DATA SOURCES & DATA COLLECTION PROCEDURES

The case study is not intended to unveil new historical evidence, but to test the overall logic of the phase-based DILC-model and to generate insights for further conceptualization. Thus, although I draw on primary sources for quantitative indicators, the qualitative case study is a triangulation of primary and secondary accounts: mostly academic, but also from e.g. the press (mass and specialized media) and governmental sources.

V.2.1. Sources for quantitative indicators and data collection procedures

In this case study, I apply only the experimental visual examination method that aims at dividing the whole issue life-cycle in sub-periods. These will structure the case study narrative, later to be compared with the theoretical stages of the DILC-model. The visual examination also looks for initial insights about broad patterns and apparent relationships between (indicators of) attention from different domains, in order to examine the dynamic relationship between issue-attention cycles and issue life-cycles.

In this case, I will use the following attention indicators:[66]

1) *Public attention:* As a *proxy* indicator to public attention I use the number of articles on air pollution/smog in mass-circulation newspapers per year: *Chicago Tribune* (CT), *Los Angeles Times* (LAT), *New York Times* (NYT), *Washington Post* (WP) and *Wall Street Journal (WSJ)* (Figure IV.2 and Figure V.3.a). Because smog is an issue that severely affected Los Angeles (California), the public attention dynamics indicated by the *Los Angeles Times* (LAT) is quite different from the rest of the Nation[67], so that the visual representation shows the average number of articles per year in the CT, NYT, WP and WSJ, and the yearly number of articles in the LAT. In order to allow an easier comparison between both curves, I represent the *standardized* values[68] in the charts.

   The data was collected through a keyword search in each newspaper's historical archives. The keywords used were 'air pollution' and 'smog' (joined with the Boolean operator 'OR'[69]). One issue with this kind of indicator and data collection strategy is that, firstly, it does not account for changes in length of newspapers or articles (however, by using more than one newspaper as a source, this issue is less of a concern). Secondly, it does not account for changes in meanings, interpretations and framings of the local air pollution issue throughout its issue life-cycle. This issue will be tackled through the narrative approach.

2) *Political (Congressional and Regulatory) attention:* To capture the dynamics of attention to air pollution and smog by policy-makers and

[66] Primary quantitative data other than for the attention charts were collected from governmental sources (e.g. the US *Environmental Protection Agency*; *Department of Transportation*) and industry journals (e.g. *Ward's*; *Automotive News*).
[67] Indeed, as the case study will show, the issue life-cycle in California followed distinctive dynamics, representing a source of pressure on higher level developments.
[68] Standardized values show how many standard deviations the particular yearly value is from the whole period (1940-1990) average value.
[69] Or equivalent strategy, depending on operators available for each database.

regulators, I look at two indicators, respectively: *the number of bills introduced in Congress to regulate air pollution* and *the number of publications on air pollution in the Federal Register*[70]. For the number of congressional bills, I draw on a figure by Bailey (1998), who analysed the politics of air pollution in the US Congress. The author used a keyword search in the *Congressional Record*[71], but filtered the results to restrict outputs to 'bills' only. Bailey's (1998) data collection strategy served as an inspiration for me to look for an indicator for regulatory attention, by carrying out similar data collection strategy – a keyword search – in the *Federal Register*. Again, these indicators do not account for differences in meaning, interpretations and framings of the air pollution issue over time, making it warranted to triangulate the quantitative findings with the narrative approach.

3) *Industry 'attention'/technology development:* In this case study, I use only one indicator for industry 'attention' (or, more precisely, for industry technology development strategy): the number of emission control patents per year. This indicator has been used in studies by Lee and colleagues (2010; 2011). My data collection strategy is inspired by theirs: I used a keyword search approach, which includes issue-related words and technology-related (emission control) words.[72] I also separated the resulting patent dataset in terms of assignee groups: the Big Three American automakers (Chrysler, Ford and General Motors); foreign automakers; and regime outsiders (chemical & oil industry suppliers and others). Only assigned patents were counted, but for the visual representation, they were ordered according to the filing year and displayed as standardized values (see footnote 60).

[70] The *Federal Register* publishes US regulatory agency's notifications and rules and (presidential) executive orders, two key types of policy-implementation action at the US Federal level.
[71] The *Congressional Record* publishes transcripts of hearings, debates and speeches and bill proposals, indicating evolving attention to issues.
[72] The words used were: 'emission control, 'air pollution', 'smog', 'exhaust emission', 'catalytic converter', 'catalyst', 'thermal management system', 'crankcase ventilation', and 'vapor separator'. The search was carried out with the Boolean operator 'OR'. The technology keywords were selected based on the book by Mondt (2000). The database used was *Google Patents*, which provides a search tool for the USPTO: the advantage of using *Google* Patents instead of the USPTO search engine is that Google offers the possibility of carrying out a keyword search for all years, while the USPTO restrict keyword search to patents issued after 1968.

V.2.2. Sources for the qualitative case study (narrative)

Primary sources for protests and public discourse are articles in newspapers (the *Los Angeles Times*, the *New York Times*, the *Washington Post* and the *Wall Street Journal*) and in magazines (*Time* and *Science*). Besides articles, I also looked for political cartoons published in those newspapers and periodical, because these graphically capture public interpretations of the most pressing issues of the time. In particular, cartoons were extracted from Johnson and Katz (2009), who offer a comprehensive compilation of cartoons by the prominent *Washington Post* (liberal) cartoonist Herblock[73]; and from the book edited by the *US Department of Health, Education and Welfare* 'No laughing matter: The Cartoonist Focuses on Air Pollution' (USDHEW, 1966), which compiles air pollution editorial cartoons up to mid-1960s.

The narrative draws on many secondary sources, most of which studies that have a disciplinary bias:

- From an engineering perspective, Mondt (2000), a former engineer at GM, highlighted the technical choices and concerns in the development of various emission control systems. Heck and Farrauto (2002) offers a detailed explanation of emission control technologies based on chemical catalysis.
- From an innovation studies perspective, Lee, Veloso, Hounshell and Rubin (2010) and Lee, Veloso and Hounshell (2011) analysed the technological changes through an in-depth patent and cost (learning curve) analysis; while Nill and Tiessen (2005) studied different technological trajectories (namely catalyst and lean burn engine), and how one of them became dominant through interactions between technological, competitive and policy developments.
- From an economics point of view, Crandall *et al.* (1986) made a cost-benefit analysis of the air pollution regulations, weighing the health and environmental benefits against the pecuniary costs of regulations to the

[73] Herbert Lawrence Block, winner of three Pulitzer prizes for editorial cartooning, and co-winner of a fourth Pulitzer prize for Public Service on the Watergate scandal (Johnson and Katz, 2009). After his death, Herblock deserved two exhibitions in the US Library of Congress (available at: http://www.loc.gov/rr/print/swann/herblock/ and http://myloc.gov/exhibitions/herblock/Pages/default.aspx, both last accessed on August 12th, 2013).

industry and consumers. Bresnahan and Yao (1985) address other non-pecuniary costs, such as the influences of catalytic converters on driveability and fuel efficiency of cars.

- Krier and Ursin (1977) provided a detailed chronological account of the internal policy process, focusing on agenda building, negotiations in committees, decision making in Congress, implementation, etc. In particular they focus on the various interactions between the federal level and the state level (especially California). Dewey (1999) retells the history of the 'anti-trust case of the century', in which American automakers and their trade association were judged by the Supreme Court for alleged anti-competitive behaviour in the development of emission control technologies.
- Gonzales (2002a; 2002b) looked at the politics of air pollution regulation and automobile emissions from a critical Marxian perspective. Luger (2000) and Doyle (2000) make a broader political economy analysis, focusing on the interactions between policy-makers and car industry, and the corporate political strategies the latter employ.

From the TEF perspective, it thus appears that previous studies have addressed important *single* dimensions of the local air pollution issue life-cycle. I will draw on these studies to focus on the *interactions and spillovers* between the various dimensions in order to develop a more comprehensive and multi-dimensional analysis based on the DILC-model. I will also use secondary accounts of broader contextual developments affecting the American automobile industry (White, 1971; Abernathy *et al.*, 1983; Yates, 1983; Halberstam, 1987; Flink, 1990; Ingrassia and White, 1995; Freeland, 2001; Studer-Noguez, 2001; Hyde, 2003; Ingrassia, 2010) to analyze how other issues (such as safety, fuel efficiency, competition from foreign new entrants, market fluctuations and financial problems)[74] influenced or not the air pollution issue life-cycle.

V.3. QUANTIFICATION APPROACH: ANALYSIS OF ATTENTION INDICATORS

Figure V.3 present the representations of the attention indicators: (a) public attention to air pollution and smog; (b) congressional attention to air pollution and

[74] Some of the issues to which I pay less attention are labour relations, international markets, consumer finance provided by car companies, and internal company struggles.

smog; (c) regulatory attention to air pollution and smog; and (d) emission control patents ('industry attention') by assignee type. Here I provide a visual analysis of how each indicator behaved through time and how they appear to be related to one another. The analysis is triangulated with my qualitative knowledge of the case in order to arrive at the sub-periods:

a) Air pollution and smog received rising levels of attention in California already in the mid-1940s, nationwide attention remained relatively low and stable in the first decade of the issue life-cycle (Figure V.3.a). In fact, public attention in California begins to increase fast by 1953, while nationwide attention to air pollution shows a slow upwards trajectory up to 1964. In qualitative terms, the issue received a compelling scientific framing in the early 1950s, after Dr. A.J. Haagen-Smit (California Institute of Technology) described the photochemical reaction that converted pollutants from automobiles (and refineries) into smog (Krier and Ursin, 1977). In 1953, American automakers formed (together with members from the oil industry) an inter-organizational alliance around the issue (Gonzales, 2002b): the *Air Pollution Foundation*. In the same year, the automakers established a *Vehicle Combustion Products Committee* within their main trade organization *Automobile Manufacturers Association* (AMA).

   Nationwide attention to air pollution follows a peak and burst in the 1960s, peaking again in 1970, when the first Earth Day was celebrated. It followed however a downward trend until late 1980s. In California, attention peaked again in the early 1980s, coinciding with environmental scandals of the Reagan[75] presidency (Dunlap and Mertig, 1992).

b) At the Federal policy-making level, air pollution received some attention in the mid-1950s, with a few bills being introduced in the House of Representatives (Figure V.3.b). However, in the mid-1960s, considerably more attention was devoted to the issue, both in the House and in the Senate. This peak and bust cycle of political attention is in line with nationwide public attention in the period. After peaking during the 1969-70 Congress (together with the peak in public attention), the number of bills and political activities to regulate air pollution declined sharply, but rises

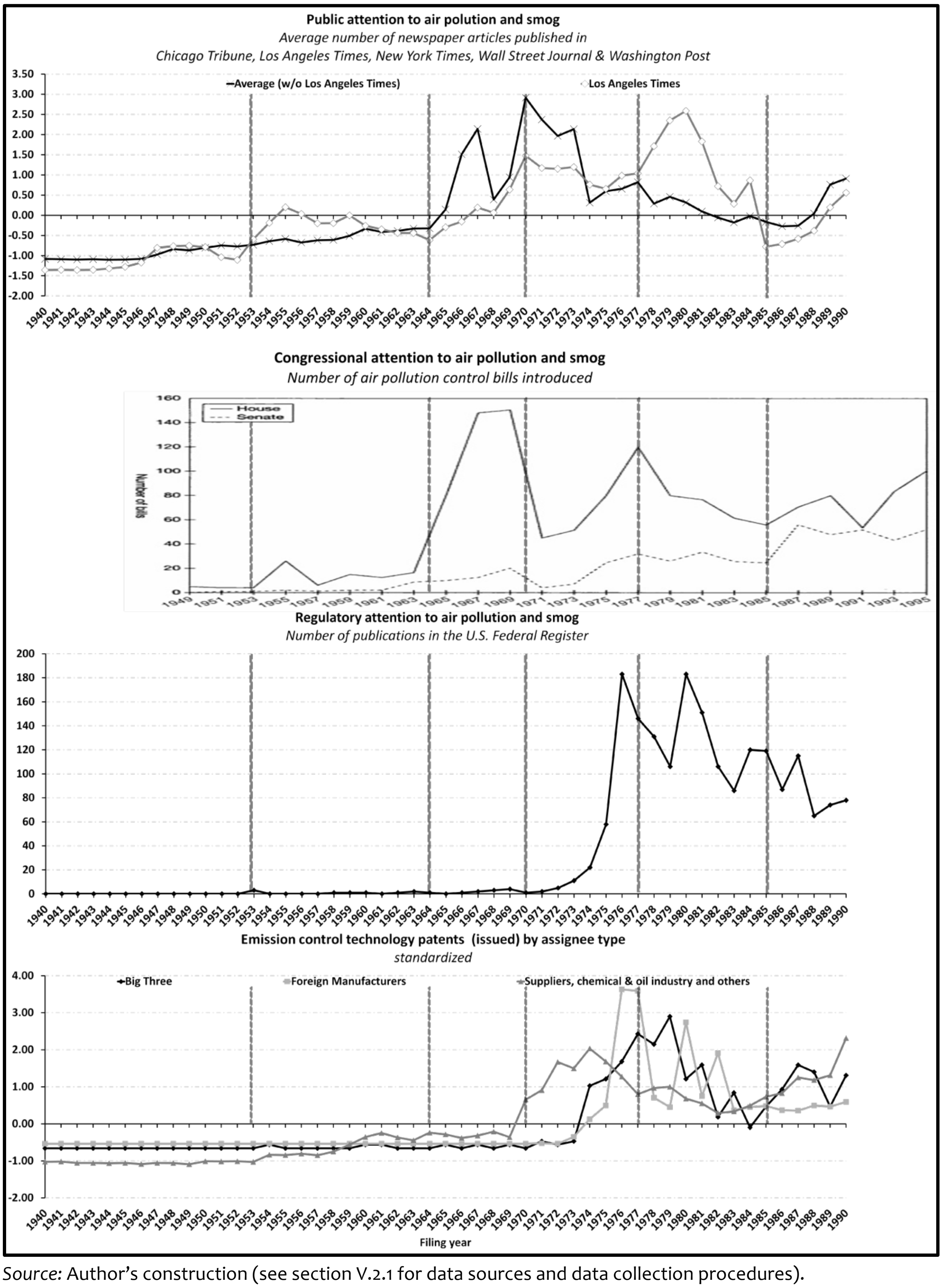
[75] Ronald Reagan was Governor of California from 1967 to 1975.

again in 1977-78, when amendments to the Clean Air Act (CAA) were voted. The curve follows a downward trend until 1990s, when new revisions to the CAA were in order.

c) Regulatory attention (Figure V.3.c) followed the establishment of the US *Environmental Protection Agency* by the 1970 Clean Air Act (Doyle, 2000). It peaks in 1976, but fluctuates at a relatively high level until the 1980s. The peak in public attention to air pollution in California in the early 1980s seems related to Federal executive level developments.

d) Patenting activity by American automakers, foreign automakers, suppliers and others (Figure V.3.d) only starts to increase in the late 1960s. Most patenting activity is concentrated between 1973 and 1983. This may indicate an *innovation race*. Yet, suppliers seem to have reacted to the first wave of public and political attention or to have anticipated the CAA policy-making process; domestic and foreign automakers seem to have reacted to policy-making and implementation (regulatory) activities, respectively. In a sense, this confirms the idea that outsiders are the first to react to the emergence of an issue that demands technical solutions.

Figure V.3 (a-d, top-down): Attention to air pollution and smog indicators



Source: Author's construction (see section V.2.1 for data sources and data collection procedures).

This exploratory visual analysis, triangulated with qualitative knowledge of the case, leads me to establish five breaking points in the case study[76]:

- 1953, when air pollution was an issue already experienced in many metropolises (Doyle, 2000), so that American automakers recognized the issue as such (accepting the technological framing);
- 1963, when an early policy-making process took place, with accompanying increased attention to the issue;
- 1970, when the first *Earth Day* was celebrated and the Clean Air Act was established;
- 1977, when Congressional attention peaks again, but public attention enters a downward trajectory;
- 1985, when public attention reaches a low, regulatory attention starts declining and patenting activities is also at a low level.

The case study will look in depth into *five* periods, to allow comparison (pattern-matching) with the five phases of the DILC-model:

1) The first period, from 1940 to 1953, is characterized by severe occurrences of smog in California (1943, 1946, 1949), emerging public concerns, and sense-making efforts.
2) The second period, from 1953 to 1963, is characterized by policy and industry learning (with early policy action in California); political debates; and industry voluntary action through a collaborative R&D program (via the industry's 1953 *Vehicle Combustion Products Committee*).
3) The third period, from 1963 to 1970, saw the first substantial regulatory efforts, in the form of the implementation of California's *Motor Vehicle Pollution Control Act* (1960) and the establishment of the first Federal *Clean Air Act* (1963). These regulations spurred the industry to develop and implement some incremental refinements to engine components.
4) The fourth period, from 1970 to 1977, starts with *Earth Day 1* (1970) and the tough *Clean Air Act* amendments (1970), and involves industry moving

[76] This periodization therefore rests on a qualitative assessment as much as on a quantitative assessment. The objectivity of a periodization based on a visual analysis of charts will be put to test through the use of statistical tests for unknown structural breaks in Chapter VII.

towards add-on oxidation catalysts, which required new (chemical) capabilities.

5) The fifth period, from 1977 to 1985, saw postponements of the standards via the 1977 *Clean Air Act Amendment*, and another innovation spurt towards three-way catalytic converters, which entailed architectural reconfiguration of engines and new capabilities in electronics. (This period will briefly refer to developments after 1985, in the run to the *Clean Air Act* revisions of 1990.)

V.4. QUALITATIVE APPROACH: IN-DEPTH NARRATIVE

To investigate how the case matches or not with the core mechanisms in the DILC-model, I analyse the evolution of the issue of air pollution (smog) and the responses from the car industry through an in-depth narrative. Following my proposed case study protocol, for each period I will discuss: (1) various pressures around the air pollution issue, (2) car industry responses; and (3) broader industry developments and strategies that affected the issue life-cycle.

V.4.1. Issue emergence and sense-making attempts (1940-1953)

V.4.1.1. Pressures around issue

Social movements and public opinion. Historically, air pollution had been associated with a prospering industry (Figure V.4), and, indeed, fossil fuel burning by industry is a major cause of the so-called London-type fog (Mondt, 2000). The issue of 'smog' (local air pollution), however, emerged in California in the 1940s where the combination of a unique topography and meteorology and widespread car usage formed conditions for its creation (Gonzales, 2002a). Los Angeles in particular began to experience a general haze over the city, which caused eye irritation, coughing, chest and upper respiratory discomfort. There, smog was common occurrence, especially in summer, and episodes of severe smog happened in 1943, 1946 and 1949 (Krier and Ursin, 1977).

This state of affairs gave rise to public concerns that "would be aired through letters to the editor, newspaper articles, and the occasional public demonstration" (Gonzales, 2002a, p. 134). The *LA Times* engaged in attention advocacy and in 1946 started a campaign to 'banish smog, [and] bring the sun back'. An editorial suggested that: "After several years of surveys by city and county-appointed commissions the finger of suspicion points to the manufacturing and industrial districts in the south and southeast of Los Angeles as the principal offenders" (Los Angeles Times, 1946).

Figure V.4: 1936 Cartoon on air pollution as a consequence of economic prosperity

Source: Johnson and Katz (2009)

Policy-makers. Although local policy-makers expressed some concerns about smog, they did not go beyond "well-publicised but essentially token enforcement efforts" (Gonzalez, 2002a, p. 134). Yet, scientific research into LA-type smog received important impulse in 1947, when the LA County established the *Air Pollution Control District* (APCD). Two years later, the APCD announced the findings of a research effort in cooperation with Dr. Haagen-Smit, that organic peroxide was involved in the creation of smog (Los Angeles Times, 1949). In 1950, Haagen-Smit described the photochemical reaction that converted pollutants into smog and pointed to automobiles (and refineries) as main sources of LA-type smog (Doyle, 2000; Krier and Ursin, 1977).

V.4.1.2. Car industry issue responses

Issue-related pressures on the car industry were relatively weak throughout the 1940s. When Haagen-Smit published his findings, however, the industry promoted public information strategies to deny the 'hypothesis' (Luger, 2000; Gonzales, 2002a). The oil industry also engaged in an early framing struggle, and sponsored research from the *Stanford Research Institute* (SRI) to refute Haagen-Smit's findings. The SRI contested the fundamentals of his research, and argued that smog was still a mystery (Doyle, 2000; Krier and Ursin, 1977).

In 1953, with their legitimacy under threat, the car industry and the oil industry decided to form a research alliance – the *Air Pollution Foundation* – to investigate the issue (Doyle, 2000; Gonzalez, 2002a). American automakers (GM, Ford, Chrysler and American Motors) also established the *Vehicle Combustion Products Committee* (within the *Automobile Manufacturers Association*), announced as a collaborative effort to develop emission-control technologies.

V.4.1.3. Influences of broader industry trends and contexts on issue life-cycle

In the immediate post-World War II (WWII), the broader industry context was highly favourable to American automakers. The car industry enjoyed high political legitimacy, because of its weapon manufacturing effort during the war, and because of post-war economic and employment contributions (Halberstam, 1987; Luger, 2000). Culturally, the car became an American icon, representing modernity and progress (Flink, 1990). Demand for passenger cars boomed after WWII, with passenger car sales achieving a record of 5.8 million in 1953 (Ward's Automotive Group, 2011). The Big Three accounted for 91% of the market (Ward's Automotive Group, 2013). In this favourable scenario, the American car industry paid little attention to air pollution. In fact, the industry's *economic (positioning) strategy* was oriented towards the sale of more profitable large-cars (Flink, 1990), which were less fuel efficient and thus polluted more.

V.4.2. Policy learning and defensive industry responses (1953-1963)

V.4.2.1. Pressures around issue

Social movements and public opinion. The 1953 'five-day siege of smog' (in Los Angeles) heightened public concerns (Krier and Ursin, 1977). Public pressure further increased with the formation of anti-pollution groups such as Stamp Out Smog (SOS) in 1958 (Jacobs and Kelly, 2008). Newly established environmental groups would later join and promote anti-pollution campaigns (Dunlap and Mertig, 1992), but general public attention remained low except for California – albeit increasing steadily (Figure V.3.a).

Science. With severe episodes of smog happening also in the rest of the country, the American medical community began to voice concerns about the health effect of air pollution (Bollier and Claybrook, 1986). Medical research contributed to the emergence of a new framing of smog from 'nuisance' to 'health risk' (Jacobs and Kelly, 2008) (Figure V.5).

Figure V.5: Cartoon from the early 1960s portraying the health-risk framing of air pollution

Source: USDHEW (1966)

Policy-makers. The 1953 shock event and rising public concerns led to policy debates, investigations and policy learning in California. Policy-makers began discussing the creation of *regional* pollution control districts, while California's Governor sponsored research, which confirmed that automobiles were important contributors to smog problems (Krier and Ursin, 1977). Also the federal level engaged in policy learning. The federal *Air Pollution Control Act* (1955), for instance, stimulated studies on the causes and (health) effects of air pollution. A study by the Surgeon General was debated at the *First National Conference on Air Pollution in 1958* (Gonzales, 2002a), and prepared the ground for the 1960 'Schenck Act' that made the study of motor vehicle emissions part of the remit of the Surgeon General (Doyle, 2000). In 1959, air quality was made part of the mission of the California Department of Public Health (Krier and Ursin, 1977), something that strengthened the issue's health framing. The next year, California adopted the *Motor Vehicle Pollution Control Act,* which would be "key in spurring the automakers forward" (Doyle, 2000: 24).

V.4.2.2. Car industry issue responses

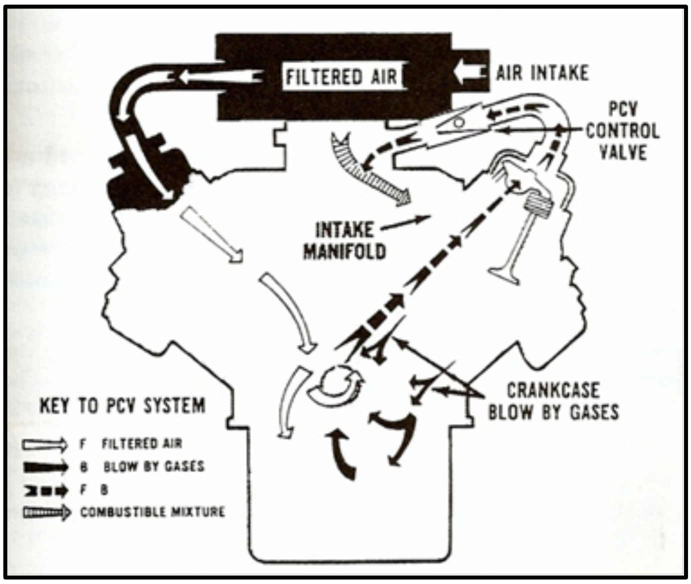
Socio-cultural and political strategies. By 1953, the car industry was still arguing that the understanding of air pollution was too uncertain to assign blame (Krier and Ursin, 1977). In a 1953 letter to Los Angeles Supervisor Kenneth Hahn, Ford argued, for instance, that its "engineering staff, although mindful that automobile engines produce gases, feels that these waste vapors are dissipated in the atmosphere quickly and do not present an air pollution problem" (quoted in Doyle, 2000, 17).

However, in 1954 the Air Pollution Foundation announced research results that *confirmed* Haagen-Smit's findings; and, in another study from 1956, the Foundation pointed the automobile as the main source of L.A. smog (Krier and Ursin 1977). Although the car industry acknowledged the findings, it pointed to 'uncertainties' and insisted on further investigations (Mondt, 2000). The car industry deployed information strategies that aimed to 'divide and rule' between state and federal levels, arguing that national regulations were not necessary because 'California was a special case' (Doyle, 2000). In a 1960 Congressional hearing, a representative of the AMA declared: "The popular term 'Los Angeles smog'… has a sound origin, because photochemical smog is… not likely to occur anywhere else on earth with the frequency and intensity found in this area" (quoted in Krier and Ursin, 1977, p. 89).

Technology innovation strategy. The car industry also adopted innovation strategies, which were coordinated by AMA's *Vehicle Combustion Products Committee*. The initiative also included a cross-licensing agreement on sharing emission control-related patents. But this was an institutional strategy as much as technological. The industry's political message was that regulations were not needed, because the industry was already working hard on solutions. And to further close the industry front, the Committee rather than individual companies would manage public communications (Luger, 2000). Thus, this IOR was formed for reasons of reciprocity and efficiency (in the development of technologies) as much as for reasons of stability and legitimacy.

But the industry did promote R&D on emission-control technologies. The research program focused on *incremental* innovations in engine components, such as the *Positive Crankcase Ventilation* (PCV) valve (a technology known since the Second World War). The valve, patented by GM in 1959, is a kind of technological 'tinkering' (Mondt, 2000): filtered air replaces the pollutants present in crankcases, which are recycled into the engine intake and mixed with the air-fuel mixture to be burned again in the combustion chamber (Figure V.6).

Figure V.6: GM's 1961 PCV system



Source: Mondt (2000, p. 53)

Although PCV devices cost only $10.00 per car[77], car manufacturers complained about the extra costs of installing pollution control devices (Doyle, 2000), indicating a new framing strategy in California, drawing on economic factors. But the industry also argued that regulations were not needed, because solutions were in the making. To demonstrate goodwill, in 1960, GM wrote to Californian officials to inform that its 1961 model-year (MY) cars sold in the state would have a PCV valve (Doyle, 2000) – which became the first innovation in response to the smog issue. In fact, GM's strategy attempted to pre-empt the need for legislation mandating emission-control technology.

There was also some work on more radical alternatives. AMA's *Exhaust System Task Group*, formed in 1955, investigated oxidation catalysts (Lester, 1983). In 1957 Ford publicly announced that it was working on vanadium pentoxide catalysts, while Chrysler also publicly announced the development of better tuned engines that produced less fumes. GM reprehended both initiatives through the

[77] In 1962 dollars (= $75 in 2011 dollars). A best-selling sedan, such as the *1962 Chevrolet 409*, cost about $2,500 in 1962 dollars (= $18,600.00 in 2011 dollars).

AMA, reminding both companies of their agreement on managed publicity and threatening them with sanctions (Doyle, 2000).[78]

V.4.2.3. Influences of broader industry trends and contexts on issue life-cycle

The cultural legitimacy of the car (and the industry) remained high, with the car fleet increasing more than 4% per annum in the 1950s, reaching more than 60 million registrations at the turn of the decade (USDOT/FHWA, 2011). The car symbolized success, status, modernity – and freedom. The car and the interstate highway system also stimulated a new kind of tourism (camping) and, consequently, renewed the public interest in 'the wild' and in national parks, which the general public could then visit thanks to cars. The car thus contributed to a new wave of 'conservationism', which resulted in the creation of environmental groups such as Nature Conservancy (1951) and the World Wildlife Fund (1961) (Doyle, 2000). This cultural change represented an early incentive for policy-makers to become somewhat more concerned with environmental issues. Yet, the main automobile-related policy issue rising on the political agenda was *safety* (Eastman, 1984).

The industry's *positioning strategy* was directed towards the large car segment, where firms competed on styling, gadgets, and costs. This focus on gadgetry to the detriment of functional technologies – such as air pollution control – became the focus of public (Figure V.7) and political criticisms (Doyle, 2000). The small-car market formed an entry point for foreign manufacturers (Yates, 1983).

[78] GM's threats became public after the 1969 Supreme Court antitrust case. This event indicates that the IOR, while apparently symmetric, was in fact asymmetric, as GM, the market leader, was able to exert power over its partners in the IOR.

Figure V.7: Cartoon from the *Washington Post* (March 4th, 1960) on automakers' reaction to 'attachments to reduce poisonous gases'

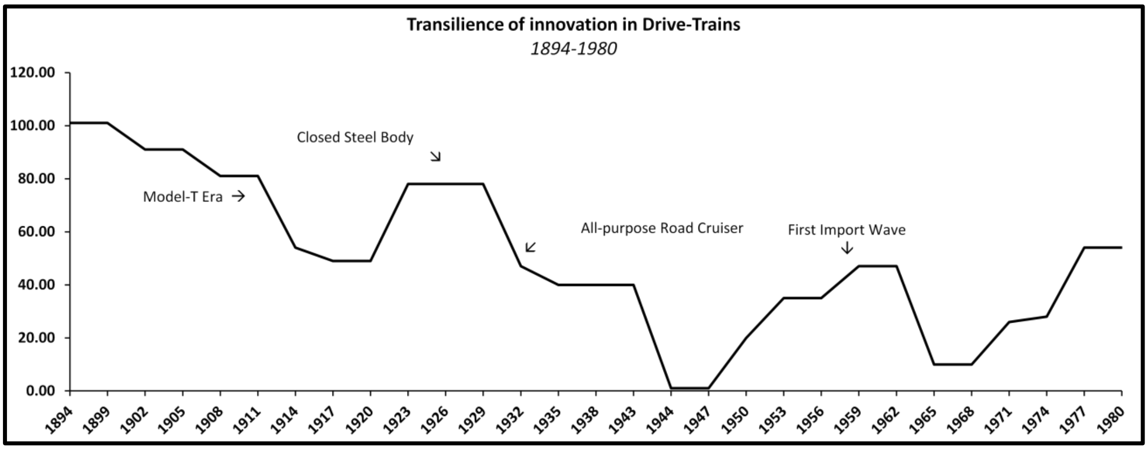
Source: Johnson and Katz (2009)

Innovation strategy remained of limited priority. "The American automobile industry [lagged] far behind foreign competition in the 1950-1980 period in developing and adopting state-of-the-art innovations that improved fuel economy, performance, handling, and safety" (Flink, 1990, p. 292). In the late 1950s, the Big Three (GM, Ford and Chrysler) responded to the foreign imports by building their own compacts models, e.g. Ford Falcon; Dodge Dart; Plymouth Valiant (White, 1971; Flink, 1990). This did entail an innovation effort and the development of new engine concepts (e.g. rear-mounted, air-cooled aluminium engines), and changes in transmissions and chassis design. Although the transilience index [79] of innovation thus briefly improved (Figure V.8), these innovations were targeted towards a special market niche, and only affected mainstream (large car) technologies to a limited extent. The transilience index subsequently went down

[79] The transilience index reflects the degree of technical difficulty of innovations over time. For the 1894-1980 period, Abernathy *et al.* (1983) construct this index for the American car industry, based on a coding of 631 technical innovations using a 7-point scale (based on how disruptive the innovation is to the production process).

again. Compact models achieved disappointing sales, which hardened Detroit's negative beliefs about the small car market (Yates, 1983). The industry's strategy towards the task environment thus continued to negatively contribute to the air pollution problem.

Figure V.8: Pattern of innovative activity of the American automobile industry



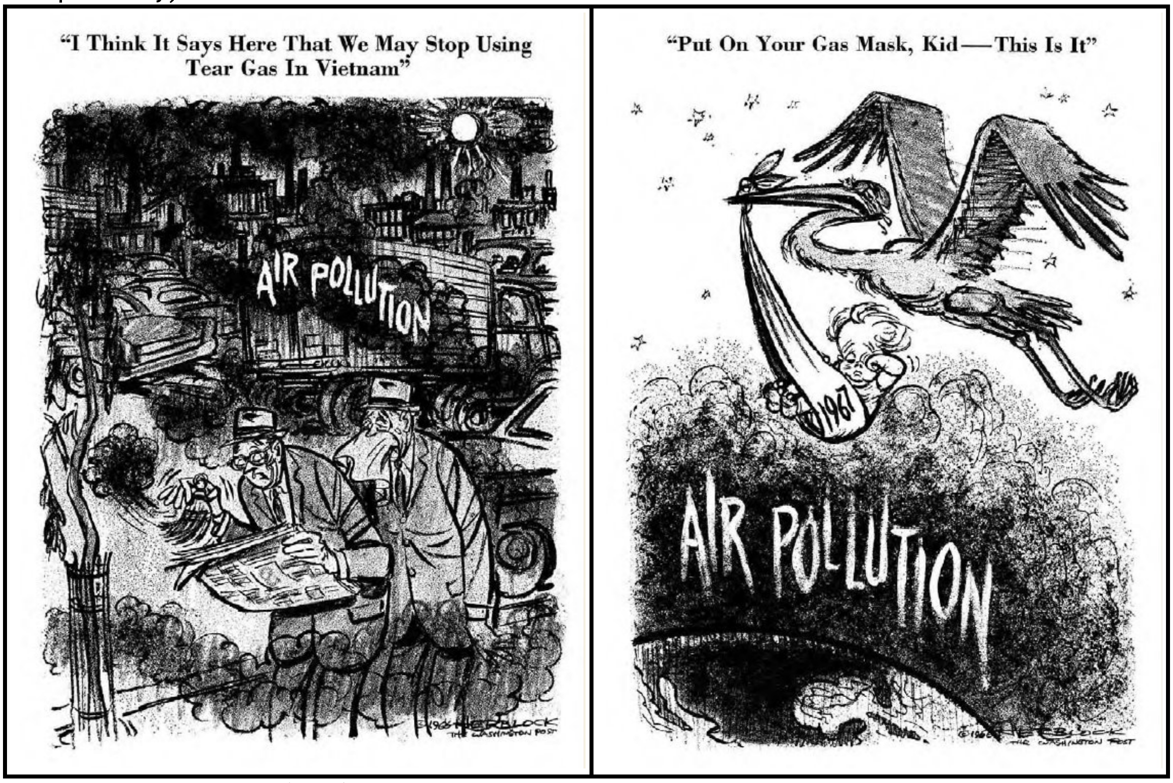
Source: Abernathy *et al.* (1983, p. 115)

V.4.3. Increasing public concern, enactment of legislation and industry delay (1963-1970)

V.4.3.1. Pressures around issue

Social movements and public opinion. Smog problems became commonplace events in states other than California (e.g. New York, Philadelphia) as car ownership increased (Doyle, 2000). The scientific understandings of health effects also grew and became publicly shared (Bollier and Claybrook, 1986; Jacobs and Kelly, 2008); thus a more widespread view that the issue was getting worse added to a new public sense of urgency, reflected in political cartoons (Figure V.9). This public framing resonated with new cultural sensitivities about environmental vulnerability (Dunlap, 1992), which had also been influenced by the debate around Rachel Carlson's *Silent Sprint* (1962), a public science book on the environmental effects of pesticides. New activist groups, e.g. *Clean Air Council* (1967) and *Group Against Smog and Pollution* (GASP) (1969), coalesced with physicians and environmental groups into a social movement, which organized protests and disseminated information about air pollution (Dunlap and Mertig, 1992; Gonzales, 2002b). Air pollution concerns increasingly spilled over to public opinion, and public attention peaked in 1967 (Figure V.3.a).

Figure V.9 (a-b): 1966 Cartoons by Herblock (September 23rd and December, 30th, respectively)



Source: Johnson and Katz (2009)

In 1969, public opinion was also influenced by an anti-trust case against the Big Three, American Motors and the AMA (Dewey, 1999; Doyle, 2000). The Department of Justice (DOJ) accused the industry of conspiracy not to compete in terms of pollution control devices (via AMA's *Vehicle Combustion Products Committee*). "Publicly, the automakers' cooperative venture appeared to be a laudable undertaking… But unbeknownst to the public, 'the agreement' would work its will on any company that stepped out ahead of the others, retarding progress, not pushing it forward" (Doyle 2000, p. 35). The industry was able to settle the issue with DOJ in a consent decree[80], but its reputation and image was severely damaged. Congressmen, citizens and social movements sent thousands of petitions to DOJ, arguing against the decree and in favour of public prosecution (Dewey, 1999; Luger, 2000). Although the decision was upheld, the event "demonstrated to many, particularly those supporting or participating in the

[80] The decree prohibited e.g. the exchange of restricted information between car manufacturers, cross-licensing of future patents, delay in installation of technologies, restriction of publicity on technological achievements, joint assessment of third party's technologies. It also required that patent licenses be made available to others. (Mondt, 2000)

growing environmental movement, that the auto industry would heed the public interest only if it were forced to by Congress" (Luger, 2000, p. 86).

Policy-makers. The original 1963 *Clean Air Act* (CAA) signalled stronger federal involvement, and was followed by a rapid increase in the number of bills introduced in the House and Senate (Figure V.3.b). Methods for controlling car emissions were not included in the 1963 CAA, because of ongoing deliberations with the car industry (Mondt, 2000). However, California, which had specified the first emission standards for car exhausts in 1960 (Gonzalez, 2002b), began to mandate emission control technologies in the 1966MY. Candidate technologies were to be tested in 1964 by California's *Motor Vehicle Pollution Control Board* (MVPCB) (Mondt, 2000).

It was the *Federal Motor Vehicle Pollution Control Act* (1965) that established the first national emission standards for cars, to be adopted in the 1968MY (model year) – it however followed what the industry said was feasible (Krier and Ursin, 1977; Doyle, 2000). But as policy-makers got frustrated with the industry's delay tactics and slow technical progress, debates gradually moved towards more willingness to tighten regulations (Doyle, 2000).

V.4.3.2. Car industry issue responses

Socio-cultural and political strategies. While in the early 1960s, automakers resorted to framing strategies that claimed California was a special case (Luger, 2000), when other states (New York, Philadelphia) began introducing pollution control laws, the industry changed its position and began arguing for federal standards: "When faced with the threat of inconsistent and increasingly rigorous state laws, they… [used] their superior organizational capacities in Washington to preempt or control the environmentalists' legislative victories at the state level" (Elliott *et al.*, 1985, p.326). The political strategies used were mainly lobbying and disclosure of information in hearings (Doyle, 2000).

Technological innovation strategy. While the threat of regulation increased, the industry continued to focus on incremental improvements in combustion engine components, such as the positive crankcase ventilation (PCV) valve; evaporation-control system (ECS); air preheat by a thermal air cleaner (e.g. GM's THERMAC); and spark control, including transmission controlled spark (TCS) and a thermovacuum switch (TVS) (Mondt, 2000). In 1966, the air injected reactor (AIR), which promoted the oxidation of HCs and CO in exhaust manifolds, was successfully introduced in vehicles sold in California. These incremental innovations made it possible to meet the regulations mandated for 1966 in California and 1968 nationwide. In subsequent years the car industry focused much technological attention on thermal reactors[81], which were an extension of AIR systems.

Automakers resisted the implementation of catalytic devices developed by suppliers, a technology they did not yet dominate. Because there were some prospects that catalytic converters could be certified by California's MVPCB, in 1964 the director of the AMA recommended its members to avoid the topic of catalytic converters – 'shrug it off or ignore it' – and if they would come to be certified, then automakers should claim that there was not enough time to install them in 1966 model-year vehicles (Doyle, 2000, p. 45). American carmakers did however set up R&D programs to investigate the technology (Lester, 1983; Mondt, 2000). Ford joined the *Inter-Industry Emission Control Program* (IIEC1, 1967-1973) with outside firms to acquire new capabilities, while GM created its own catalyst R&D program (Mondt, 2000). In 1968, GM found that unleaded fuel diminished catalyst degradation, which has been a serious problem:

> *It is difficult to overstate the significance of the GM lead-free tests in the evolution of catalytic control of vehicle emissions. They demonstrated that, when operated on unleaded fuel, catalytic systems could be made durable,* [...] *and that they need not substantively impact engine operation or performance, including fuel economy.* (Lester, 1983, p. 422)

New entrants and outsiders. Outsiders such as American Cyanamid, Walker Manufacturing, and Universal Oil developed catalyst technologies (Lester, 1983) (cf. Figure V.3.d). In 1962, Engelhard Industries successfully tested catalytic converters in automobiles (Doyle, 2000). Although the MVPCB certified catalytic converters from suppliers, the industry – characterized by strong vertical integration – did not buy these new technologies, because they did not want to sell and warrant vehicles equipped with expensive devices made by third parties

[81] Thermal reactors, which operated at temperatures above 750°C, aimed to further improve the oxidation of hydrocarbons. They did not control for NOx emissions, however, and implied a fuel penalty of about 12% (Mondt, 2000).

(Mondt, 2000). Automakers adopted instead an incremental solution to meet the Californian standards for 1966, the 'Clean Air Package' (based on improved adjustment of the air/fuel ratio and spark retarding techniques) developed by Chrysler (Doyle, 2000; Mondt, 2000).

V.4.3.3. Influences of broader industry trends and contexts on issue life-cycle

The industry's public and political reputation were eroded by Nader's book *Unsafe at Any Speed* (1965), which criticized their reluctance to introduce safety features like seatbelts (Luger, 2000), and by the subsequent 'Ribicoff hearings' (1965-6), which exposed secret recall campaigns through which one in five cars had been recalled for safety defects between 1960 and 1966. "Since this revelation came on the heels of the industry's refusal to support any form of federal regulation, legislators now were inclined to see the industry as not just uncooperative but as unreasonable" (Luger, 2000, p. 72). The safety issue resonated with the air pollution issue and strengthened the political willingness to introduce stricter legislations. The rise of an 'activist culture' and new environmental groups (e.g. Environmental Defense Fund (1967); Friends of the Earth (1968); Environmental Action (1970)[82]) (Doyle, 2000) strengthened the public discourse about air pollution.

V.4.4. Tough legislation and resisted implementation (1970-1977)

V.4.4.1. Pressures around issue

Social movements and public opinion. Public pressure peaked (Figure V.9.a) during the April 1970 first *Earth Day* event, when about 20 million people (Luger 2000) participated in workshops, seminars or protest marches to 'save the planet'. *Time* magazine reported on the occasion: "Earth Day planners scheduled stunts to dramatize various aspects of the environmental crisis. (...) The biggest target of all was the automobile. In Danbury, Conn., students made ready to perform the now popular ritual of burying an internal-combustion engine. At Wayne State University they marshalled pickets for General Motors' headquarters..." (Time, 1970, online). Other type of initiative was taken by SOS, who co-sponsored a 'share-a-hide-day' – "the first organized demonstration of carpooling and bus

[82] The Greenpeace was founded in 1971.

riding" (Jacobs and Kelly, 2008, p. 220). Out of the Earth Day came also a new brand of environmental lobbying, which supported the tough *Clean Air Act* amendments proposed by Senator Muskie (Doyle, 2000). The *United Auto Workers* (UAW) joined the 'Coalition for Clean Air', which lobbied the Senate for stricter auto emissions regulations (Luger, 2000).

Policy-makers. Congress enacted the 1970 *Clean Air Act* amendments (CAA), which was a tough piece of regulation that demanded 90% reductions in HC and CO emissions by 1975 and in NO_x by 1976 (Mondt, 2000). The CAA specified a $10,000/vehicle fine for firms selling cars that did not comply (Luger, 2000).[83] The CAA was the culmination of reinforcing processes, which explain why the local air pollution issue life-cycle followed the regulatory route in the US: (a) decreasing legitimacy of automakers; (b) increasing political frustration over the industry's delay tactics; (c) macro-cultural trends such as rising environmentalism and social activism; (d) political jockeying between Senator Muskie and President Nixon (Elliott *et al.*, 1985).[84]

CAA implementation was delegated to the newly created US *Environmental Protection Agency* (EPA), which could also regulate fuels (Stikkers, 2002). Lead as a fuel additive was a matter of concern, because of its effects on human health – and on the durability of catalytic converters (Lester, 1983; Mondt, 2000). Since 1971 EPA therefore issued regulations that progressively removed lead from gasoline and ordered the sale of unleaded gasoline in 1975 (Stikkers, 2002).

The CAA pushed automakers towards more comprehensive innovations (Luger, 2000; Mondt, 2000), being regarded as a prime example of technology-forcing policy (Gerard and Lave, 2005; Lee *et al.*, 2010). But the CAA also contained a loophole, because standards could be postponed if this was in the public interest and if the requisite technology was not available. EPA would test the performance of American car models, while foreign manufacturers were required to submit emissions data (Mondt, 2000). The test procedures themselves, the outcomes of test procedures, and the feasibility of technologies formed new dimensions where

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[83] $10,000 (1970) amounts to $58,000 in 2011.
[84] Muskie, a possible candidate for the 1972 presidential elections, introduced proposals for stricter emissions in 1969. Nixon upped the ante and proposed even tougher standards (90% reductions) for 1980. Muskie then adopted similar standards but tightened the deadline to 1975 (Doyle, 2000; Gerard and Lave, 2005).

the car industry would struggle with policy-makers. The industry exploited this loophole and played a strategic game with regulators, drawing on information asymmetries. This led to an intricate regulatory process, reflected in ups and downs in regulatory outputs (Figure V.3.c). The industry adopted a confrontational stance, initially petitioning, and later suing the EPA for extensions, arguing in court that technology to meet emission standards was not yet available (Doyle, 2000; Gerard and Lave, 2005). In 1973, when the court favoured a delay, EPA postponed the HC and CO emission standards to 1976, and NO_x standards to 1977 (Gerard and Lave, 2005).

The 1973 energy crisis influenced the air pollution struggle, because it changed the public focus to economic problems and fuel efficiency. When the car industry claimed that pollution control hindered fuel economy, Congress extended standards to 1977 (HC and CO) and 1978 (NOx). In 1975, EPA further extended HC and CO standards to 1978, because of a new controversy involving sulphur emissions by cars equipped with catalytic converters (Lester, 1983; Doyle, 2000).

V.4.4.2. Car industry issue responses

Socio-cultural and political strategy. Following the 1970 CAA, car industry resistance was stepped up and top managers became involved, such as the vice-present of Ford, Lee Iacocca, who claimed that 'this bill is a threat to the entire American economy and to every person in America' (cited in Bauner, 2007). GM's CEO sent a letter to Senators and Representatives, claiming that developing control technologies was not feasible in the specified time frame and that costs would anyway be prohibitive. CEOs from the Big Three also formed a task force to lobby senators and urge the Nixon administration to reject the law (Doyle, 2000). So, in this period, the industry flexed its strong lobbying muscle to influence high-level (macro) politicians.

When the CAA was enacted, strategies shifted towards hindering implementation through information strategies (technical reports, testimonials in hearings), constituency-building strategies ('astroturf' campaigns), and non-compliance strategies (petitions, litigation). The argument was based on the claim that the technology was not available and that high costs would cause a business catastrophe (Doyle, 2000; Bauner, 2007). These arguments signalled a shift in information strategies at the federal level, which began to focus on economic aspects, e.g. costs of regulations, negative impact on job creation and inflation, disadvantages to consumers (Luger, 2000). Estimates suggested that catalytic converters, thermal reactors, and exhaust gas recirculation would cost $860 per vehicle (Mondt, 2000), increasing the price of best-selling cars by 30%.

To reinforce the argument, GM began an information campaign in 1972, highlighting the costs of control technologies and the penalties for fuel economy[85] and driveability (Doyle, 2000). During the EPA hearings, Ford started an informational campaign, which included press briefings, luncheons, and speeches by Ford executives. This campaign aimed at influencing public opinion and convincing communities to pressure their political representatives to change the CAA. Chrysler published newspaper ads and a booklet, which said that "even if automotive engineers could meet the 1975-76 federal motor vehicles standards (...) Chrysler... would oppose them because they are wasteful, unnecessary and unrealistic..." (Doyle, 2000, p. 89).

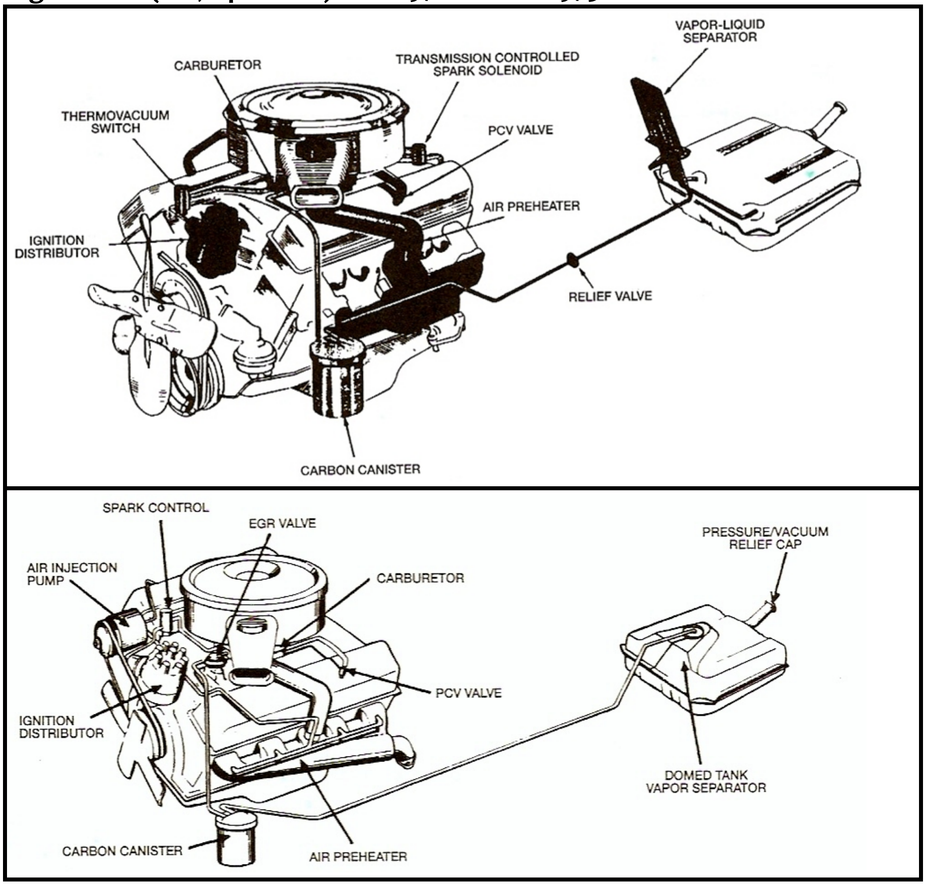
Foreign new entrants undermined the industry's claims about technical unfeasibility during congressional hearings. In 1972, Honda reported that its Compound Vortex Controlled Combustion (CVCC) engines already met CAA standards. Mazda and Mercedes-Benz made similar claims for their rotary and diesel engines, respectively (Doyle, 2000). Catalyst suppliers (such as Engelhard Industries) challenged the industry's claim that catalytic converters presented too many problems (*idem)*. Figure V.3.d shows how catalyst supplier (and latter, foreign manufacturers) stepped up their patenting activity during the early implementation process.

Innovation strategy. While American automakers collectively delayed on the political and public fronts, they individually stepped up their innovation efforts, which resulted in more patents on emission control technologies (Figure V.3.d). Initially they focused on further incremental engine modifications, adding air pumps, spark retardation, thermal afterburners, and exhaust gas recirculation to existing engines (Mondt, 2000) (Figure V.10). Because these modifications had negative effects on fuel economy, performance and driveability (Lester, 1983; Mondt, 2000), the industry gradually moved towards catalytic converters (Nill and Tiessen, 2005). Ford and, in

[85] This was due to the use of thermal reactors and other fuel-burning technologies (Mondt, 2000).

particular, GM were catching up fast with catalyst suppliers, which had the technological lead (Lee *et al.*, 2010; cf. Figure V.3.d). GM pursued an internal innovation path, while Ford joined the second *Inter-Industry Emission Control* programme (1974-1977), which allocated about $32 million (nominal) to various technological options, including catalytic converters (Doyle, 2000; Mondt, 2000).

Figure V.10 (a-b, up-down): GM 1971MY and 1973MY incremental emission control systems



Source: Mondt (2000)

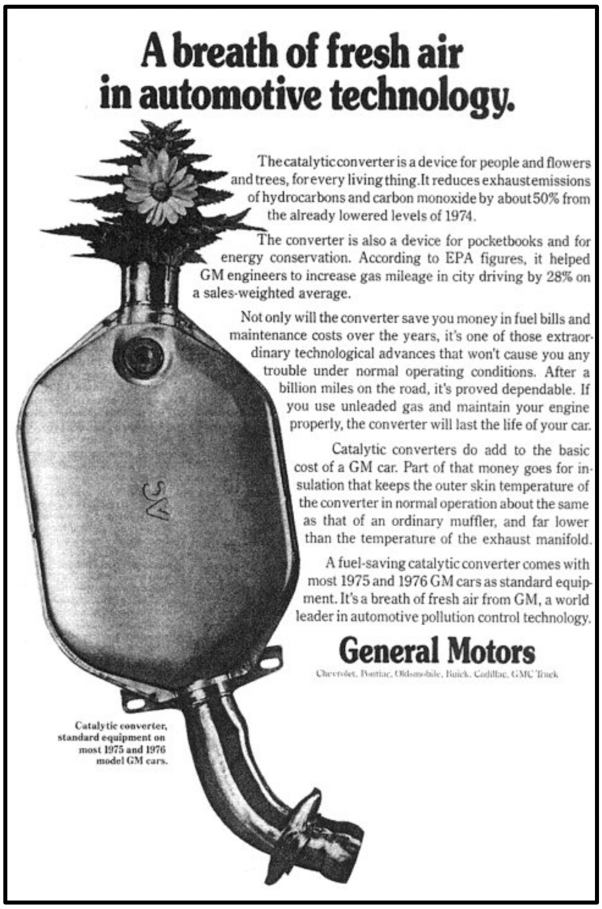
GM clearly pursued a dual strategy, joining the industry front to fight the CAA, while also becoming a product champion for oxidation catalysts[86] (Figure V.11). During the EPA hearings, GM suggested that the catalytic converter was the best emissions control technology, but complained about the time frame of the HC and CO standards (Doyle, 2000).[87] GM also asked for a review of the NO_x standard,

[86] GM's president Ed Cole, with engineering background, was in fact championing the device since GM's breakthrough with unleaded gasoline.

[87] Ford and Chrysler, however, resisted both the CAA and catalysts. This led to a technical struggle over the question of whether platinum-lined catalysts promoted the conversion of sulphur into sulphuric acid mist, as research from Ford and Esso Research and Engineering, Inc. suggested. If this was indeed true, EPA would hinder the use of oxidation catalysts (Science, 1973, p. 368). GM resolved this problem in 1975 by promoting an experiment in its testing grounds, for which both EPA and other manufacturers were invited. The experiment showed that sulphuric-acid concentrations were substantially lower than EPA's testing model (Lester, 1983).

because oxidation catalysts only diminished HC and CO emissions. However, in 1973, it announced that catalytic converters would be standard item in 1975MY cars. With this surprise move (Ingrassia and White, 1995), GM attempted to gain competitive advantage in the subsequent innovation race, e.g. using patents to create barriers for competitors, licensing catalytic converters to Nissan and American Motors (WSJ, 1977; WSJ, 1979), and apparently exploiting its investments in South African platinum futures (Science, 1973, p. 371).

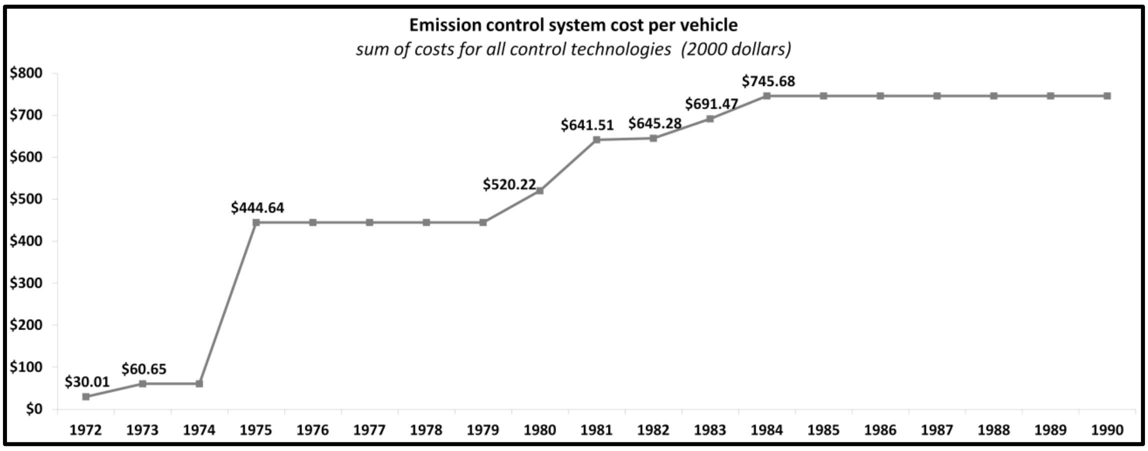
Figure V.11: 1975 advertisement by GM



Source: Google newspaper archives search

The introduction of catalyst technology in the 1975MY increased car prices by $444.64 per vehicle (in 2000 dollars, see Figure V.12). Retooling of production lines raised capital expenditures from $242 million in 1974 to $1.57 billion in 1975, a 549% increase (Gerard and Lave, 2005).

Figure V.12: Emission control technology cost per vehicle (sum of costs for all control technologies such as catalytic converters, EGR units etc.)

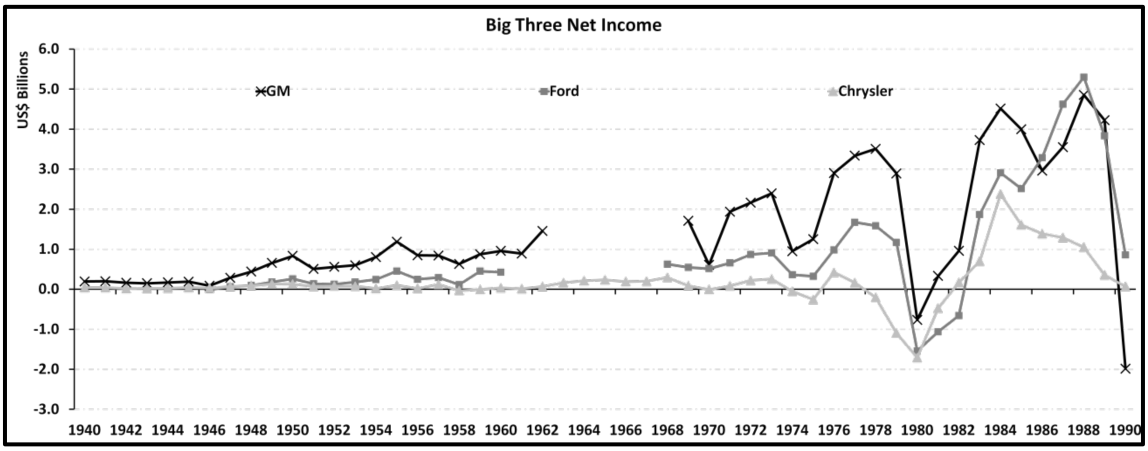


Source: USEPA (1990, p. C-19)

V.4.4.3. Influences of broader industry trends and contexts on issue life-cycle

The 1973 energy crisis not only diminished media attention for environmental problems (Dunlap, 1992) and air pollution (Figure V.3.a), but also contributed to an economic recession from late 1973 to early 1975 (3.1% fall in GDP). The recession impacted the results of the Big Three, but only Chrysler posted losses in 1975 (Figure V.13). Following the crisis, Detroit automakers emphasized trade-offs between pollution control and fuel efficiency (Luger, 2000) to gain delays. Despite this resistance against regulations, the external pressures also brought *innovation* back on the agenda of corporate strategists: "The energy shocks of the 1970s, coupled with the government mandates for clean air, ended Detroit's technological stagnation" (Yates, 1983, p. 202).

Figure V.13: Net income of the Big Three car companies, current dollars



Sources: Freeland (2001) for GM; Hyde (2003) for Chrysler; and Studer-Noguez (2003) for Ford

V.4.5. Industry fight-back, further implementation delays, issue institutionalization, and industry adoption of three-way catalytic converters (1977-1985)

V.4.5.1. Pressures around issue

Social movements and public opinion. Public attention for air pollution diminished nationwide[88] (Figure V.3.a), while attention for the car industry's economic problems increased. The Big Three posted substantial losses in the late 1970s (Figure V.13), and Chrysler had to be rescued with a $2 billion bailout package. A new anti-regulation discourse gained prominence: "Government regulation came to be blamed for the nation's economic difficulties. (...) By the end of the decade, public debate was framed around the costs of regulation, and less and less was heard about its benefits" (Luger, 2000, p. 90). Fearing unemployment, the United Auto Workers abandoned the anti-smog coalition and joined the car industry in lobbying for delays in emission standards (Figure V.14). In 1977, the UAW urged its members to pressure political representatives to delay emission standards (Doyle, 2000; Luger, 2000).

Figure V.14 (a-b): 1977 cartoons on the UAW joining the auto industry coalition in the lobbying effort agains emission standards

Source: Johnson and Katz (2009)

[88] Except for California, where public sensitivity to smog led to outrage towards Reagan's environmental scandals.

Policy-makers. In 1977, the American automakers began producing cars that would not meet the air pollution standards for 1978. This illegal action challenged Congress to shut down factories (as the $10,000/car fine would lead to bankruptcies) or postpone the standards. This led to hearings during which Senator Muskie angrily characterized the industry's attitude as: "We're too important. There are too many jobs involved. We'll break the present law and dare Congress to do anything about it" (cited in Doyle, 2000, p. 126). Policy-makers gave more prominence to economic support than to air pollution, so that Congress gave in and postponed the standards instead of shutting down factories (Doyle, 2000). HC and CO standards were pushed back to 1980 and 1981, respectively, while the NO_x standard was relaxed (from 0.4 to 1.0 g/mile) for 1981 cars (Gerard and Lave, 2005). After 1977, a decreasing number of bills regulating air pollution were introduced in Congress (Figure V.3.b).

The new Reagan administration (since January 1981) was sympathetic to the industry's complaints and set up a *Task Force for Regulatory Relief*. But when the administration advanced a plan to roll back more than 34 safety, emissions and fuel economy regulations (cf. Figure V.3.b, which shows a peak in executive activities during the Reagan years) there was a backlash (Luger, 2000). Opinion polls showed that the public generally supported environmental protection, and that this support was growing in response to the administration's attacks on environmental regulation (Dunlap, 1992; Luger, 2000). The administration decided not to push ahead, because its reputation had already been damaged by other environmental controversies (such as firing the head of EPA) (Doyle, 2000), and the bill eventually died in Congress for lack of support. Although the administration was unable to roll back clean air regulations, it stopped further legislative progress until 1990, when a revised clean air act was enacted (Lee *et al.* 2010; Bauner, 2007).

V.4.5.2. Car industry issue responses

Socio-cultural and political strategies. The economic problems emboldened the industry's political strategies, which simply refused to comply with 1978 CAA standards and threatened to shut down plants. The industry also adopted other political strategies such as setting up 'grassroots' (astroturf) movements to pressure congressmen. Chrysler, for instance, asked employees to use their names in mailgrams to representatives (Doyle, 2000). The industry also mobilized supporters inside Congress, such as Representative Dingell from Michigan, to delay bills in hearings and propose alternative (weaker) bills. The industry supported Dingell's efforts, with the auto dealers and Big Three lobbying Republicans and the UAW going after Democrats (Doyle, 2000). This lobbying task-force thus represented an informal closed-industry front against regulatory pressures in face of economic troubles.

The industry used framing strategies based on economic arguments (cost-benefit analysis as in Crandall *et al.*, 1982; Bresnahan and Yao, 1985), arguing that strict regulations would damage economic competitiveness and that emission control technologies would bring non-pecuniary costs, such as on fuel efficiency.[89] In 1979, "with the industry as a whole in crisis, industry officials approached the federal government for changes in virtually every aspect of public policy that affected them" (Luger, 2000, p. 104).

Technological innovation strategies. When the CAA standards were postponed, the industry downscaled its R&D efforts, leading to decreased patenting activity since 1977 (Figure V.3.d). By then, the industry already had developed the basic technology for the three-way catalyst (Lee *et al.*, 2010).[90] The three-way catalyst (TWC), which could simultaneously control emissions of HC, CO and NO_x, entailed architectural innovations in the engine, based on electronic control, oxygen sensors, and feedback mechanisms that were necessary to keep the air/fuel ratio within a narrow operational window. Because automakers lacked electronic competencies, outside electronic suppliers became involved (Lee *et al.*, 2010; see also Figure V.3.d).

In the 1981MY, GM introduced an 'emission control system' that included (Mondt, 2000)[91]: (1) the three-way catalytic converter; (2) an oxygen sensor;

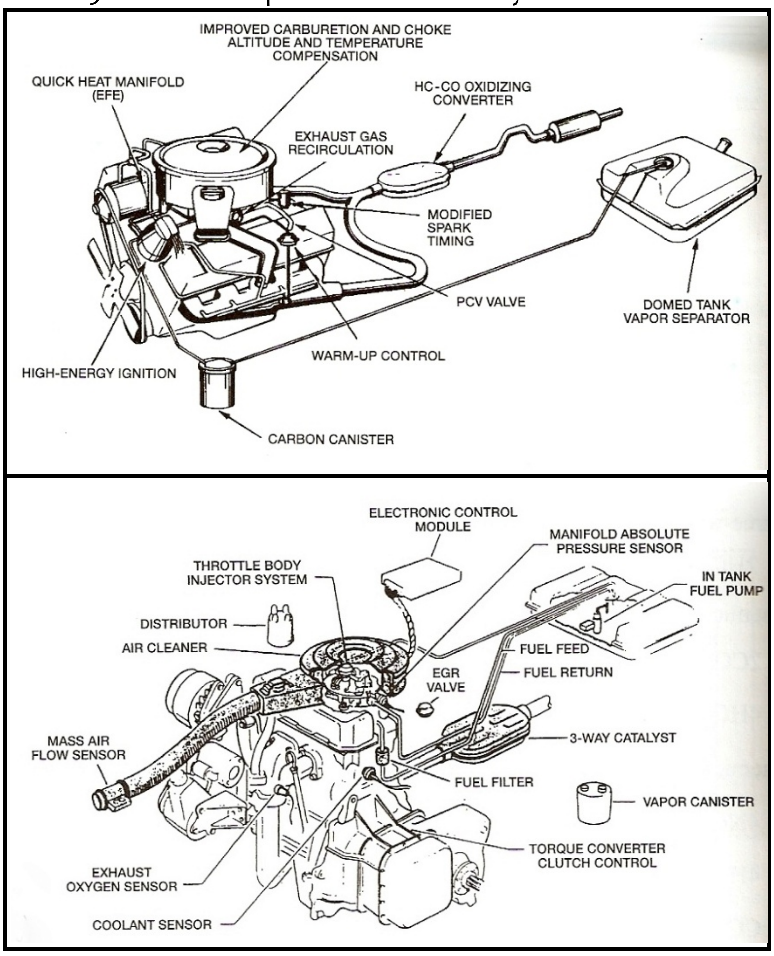
[89] The industry thus downplayed the evidence that the introduction of the catalyst in 1975 had actually improved fuel efficiency. The phase-out of lead as a gasoline additive did, however, diminish engine performance, because automotive engineers had not yet learned how to make high-horsepower engines run without the performance enhancing properties of lead (Ingrassia, 2010).

[90] A content analysis of patents shows that GM filed an "Air-fuel ratio sensor" patent in 1973 (Riddel, 1974) and a "Process for improved 3-way emission control" patent in 1976 (Schlatter and Taylor, 1978). Ford also had patents related to three-way catalyst (e.g. Stewart, 1975).

[91] GM's move was apparently a reaction to Mitsubishi Motor's announcement (in 1977) of a new engine that could both comply with the stringent NO_x standards and improve fuel economy (Doyle, 2000; Nill and Tiessen, 2005).

(3) electronic control module, which controlled several parameters such as oxygen concentration and carburettor mixture; (4) electronic ignition; (5) closed-loop carburettor; (6) early fuel evaporation system; and (7) exhaust gas recirculation. This system could lower emissions level by 96% for CO and HC and 76% for NO_x (Mondt 2000). The three-way catalytic converter system is thus more complex than early oxidation catalyst systems (Figure V.15). "The total device is a very sophisticated electronic control system to maintain the air:fuel ratio within the narrow window, which allows the conversion of all three pollutants. [...] Even today, the oxygen sensor is the state of the art in air:fuel ratio control in the gasoline internal-combustion engine" (Heck and Farrauto, 2002, p. 85-6).

Figure V.15 (a-b, up-down): GM's 1975 Emission Control System with catalytic converter and GM's 1981 Closed-loop emission control system



Source: Mondt (2000)

Although the implementation of TWC devices added another $200 to the cost of cars (Figure V.12), industry resistance was lesser than in the early 1970s. One reason is that the industry had more time following the 1977 amendments. Another reason is that the industry had already developed relevant technical capabilities. A third reason is that the industry learned that electronic controls could also be used for general engine improvements, especially when combined with fuel injection (Gerard and Lave, 2005).

The period of regulatory stability that began with the Reagan administration gave time for the industry "to learn ways to reduce their costs since they faced no stringent increases from 1981 until 1994" (Lee *et al.*, 2010:259). Developments in e.g. material technology[92] improved the catalyst's life and made it more resistant to higher temperatures (Heck and Farrauto, 2002). Technological development of catalytic converters continued in an incremental pace, with responsibility shared between suppliers and automakers (Lee et. al, 2010; cf. Figure V.3.d).

Although with the TWC CO and HC emission levels nationwide were lowered by 96%, cuts in NO_x emission reached only 76% (compared to 1960s levels) (Mondt, 2000; see Figure V.1), i.e. lower than the 90% cut in emissions of all three pollutants that the original CAA established in 1970. Original 1970 NO_x standards were only met after the 1990 CAA revisions finally mandated them by law (Doyle, 2000). Thus, in the absence of policy provisions, improvements in TWC designs and technical characteristics did not lead to further cuts in emissions.

V.4.5.3. Influences of broader industry trends and contexts on issue life-cycle

The environmental movement declined in the mid-1970s, which eased the pressure on the car industry. Ironically, Reagan's anti-environmental activities stimulated a resurgence of concern and activism, which contributed to the societal institutionalization of environmental consciousness (Dunlap, 1992).

In the task environment, the car industry faced economic problems as overall markets (for cars and trucks) declined in 1979 (-8.23%), 1980 (-19.14%), 1981 (-5.82%) and 1982 (-2.23%) (Ward's Automotive Group, 2011). Cumulatively, the Big Three lost about $4.73 billion between 1980 and 1982 (Figure V.13). Consumers increasingly preferred Japanese cars because of higher quality, fuel efficiency, and lower price, so that American automakers' market share declined steadily, with GM's market-shared going below 40% for the first time in history in 1986 (Ward's

[92] Another focus was on improving fuel injection system (Mondt, 2000).

Automotive Group, 2011). Between 1984 and 1990 the economic tide turned for the better when the Big Three made record profits (Figure V.13). In sum, in this period, due to its economic troubles, the industry gained the upper hand with regard to institutional pressures around air pollution, and benefitted from political support measures.

V.5. ANALYSIS

V.5.1. Pattern-matching of DILC- model and case study

This section confronts the empirical periods with the ideal-type phase-model. The case study confirms the overall logic of the DILC-model: the air pollution issue life-cycle was a long and contested ('dialectic') process played out on various dimensions. Air pollution emerged as an issue on the periphery of the industry, gradually spilling over between domains. As institutional pressures built up, the issue spilled over to the economic environment (through policy) and forced it to make adjustments in the industry regime. Regarding the match between periods and phases, the case study had a relatively good match (minor deviations) with the first three conceptual phases, but deviated (major deviations) from the fourth and fifth phase.

In the first period pressure came from civil society, as suggested by the model. The car industry largely ignored the issue or denied its involvement, not moving beyond its 'zone of indifference'. One small deviation from the phase-model was that early pressure and attention advocacy came from newspaper activism (L.A. Times). A second minor deviation was that sense-making was also informed by scientific research.

The second period started when new social movement organizations enacted pressure and engaged in attention advocacy, leading to minor spillovers to public opinion (slow increase in public attention except for California). A shock event (the 'five-day siege of smog' in California) and scientific research (including the initiation of a dramatic 'health framing') both played important roles in rising general concern with the issue. The industry responded by creating collective organizations to investigate the problem. Although the car industry acknowledged the contribution of the car, it delayed solutions by stressing the need for further investigations. It created the *Vehicle Combustion Products Committee*, which represented a closed front on the technical dimension, but also served as public-relation strategy. So, the case study confirms the notion that the industry responds collectively to institutional pressures in earlier stages of the issue life-cycle. One deviation is that the industry investigated technical alternatives (e.g. Ford's early work on catalytic converters) and not just incremental solutions.

The third period was close to the predicted pattern in the sense that the issue spilled over to the policy domain when public opinion became more concerned (i.e. public attention increased considerably). So, the third period was of political debate, but also entailed initial regulations (early emission standards). This early regulation represents a deviation, but seems connected to multi-level governance dynamics in the case (i.e. developments in California). The industry changed position and favoured tackling the issue at the national level, where it used information, lobbying and other framing strategies to delay issue progress. Yet, automakers also made incremental engine improvements, and pursued some defensive hedging towards alternative solutions such as catalysts. A deviation from the model is that there were no visible spillovers to 'moral customers'. Industry technical developments were therefore more connected to the threat of regulation and action by outsiders (suppliers) looking for mandated markets.

The fourth period matched the model in the sense that strict regulations were introduced (1970 CAA). This was followed by a decrease in public attention to the issue, so that the CAA represented a turning point in the process. However, political and regulatory attention fluctuated at high levels due to implementation struggles between regulators and the industry (as suggested in the DILC-model). The CAA also led the industry to increase R&D investments and patenting. Cracks appeared in the industry front as GM became a product champion for catalysts and sought first-mover advantages, leading to a new (within-industry) dialectical process in the issue life-cycle. These cracks helped in the implementation of the CAA, which might have suffered further delays, if the industry had maintained a closed-front in the task environment. The technological jockeying for position was accompanied by collective strategies to delay issue progress, so that GM (and Ford) got more time to catch up with catalyst suppliers. This seems to be a key reason for GM to join the collective front in the institutional environment, even though it had already decided to go for catalytic converters.[93] An apparent 'innovation race' emerged. But the fourth phase also deviated from the model in the sense that issue progression slowed down in the mid-1970s: this deviation happened due to weakening public opinion pressure, competing issues coming to the fore (oil shock, fuel efficiency, economic problems), and because the industry successfully counter-mobilized. Moreover, market demand for 'low-emission cars' never materialized spontaneously, as suggested by the model. This is a key deviation.

The fifth period also deviated from the predicted pattern, because policy and public opinion pressure further weakened, but not due to the factors suggested in the DILC-model. Furthermore, the industry only made some changes in technology and strategy, but there was no comprehensive reorientation in foundational beliefs and mission. The end of regulatory uncertainty in fact meant that issue progression remained dormant until the 1990s. So, this period did not represent the fifth stage of the DILC-model: although the air pollution issue life-cycle followed the predicted normal pattern, it was 'interrupted' between the fourth and fifth stage (Bigelow *et al.*, 1993), mainly due to lack of policy developments. The fifth period could be seen as 'phase 4.5', because (a) the issue was institutionalized in the socio-political environment but not in the task environment; and (b) the industry regime suffered changes in its regulatory and technical elements, but not in its beliefs and mission. All in all, the case followed this sequence of phases: 1 – 2 – 3 – 4 – 4.5.

These findings reinforce the qualification that the DILC-model represents an ideal-typical pattern from which real-world cases usually deviate. If real-world deviations from this pattern can be explained with the same pressures and mechanisms, then the underlying conceptual framework is still valid. This applies to this case study, where the main deviations were due to the following causal mechanisms: (a) decreasing pressure from public opinion and policy; (b) limited spillovers from the issue to consumer demand; and (c) rise of competing issues (which led to decreasing pressures). Therefore, the internal validity of the Dialectic Issue Life-Cycle model seems to be confirmed by the case study.

[93] It is not unfair to say that policy only forced catalytic converters into the market after GM had developed its own three-way catalytic converter, given that outsiders had already demonstrated technologies that could meet standards.

V.5.2. Explanation-building based on the DILC-model

V.5.2.1. Beyond the focal issue

In the introduction, I proposed to investigate how other strategic issues interfered (or not) with the local air pollution issue life-cycle. The case study showed that issue evolution cannot be fully understood by looking only at (internal) dialectic struggles. Because industry actors operate in multiple contexts, they also face other pressures from markets, civil society, and polity, which may accelerate or hinder issue life-cycles. The case therefore revealed multi-dimensional (mis)alignments between (internal) issue life-cycle and broader contexts. In the air pollution issue life-cycle, the following positive alignments with field-level developments helped the issue forward:

- In the 1960s, the emergence of environmental consciousness was a broad cultural trend that strengthened public attention for air pollution. Earth Day 1 was the culmination of this trend, which created a favourable context for the 1970 CAA.
- In the mid-1960s, public concerns around car safety damaged the car industry's reputation, and strengthened the belief that the industry was not interested in public welfare and would only act if forced.
- Competitive struggles with foreign car companies influenced the regulatory battle, because the engine innovations and information strategies from new entrants undermined the American industry's claims that the 1970 CAA standards were unfeasible.

The case study also contained negative alignments that hindered issue progression:

- The 1973 oil shock created economic problems and stimulated interest in fuel efficiency, which overshadowed cultural and political attention for air pollution.
- In the late 1970s, the industry used its economic problems to articulate an anti-regulation discourse that resonated with broader problems in the American economy. This discourse halted regulatory progress on air pollution.

These findings underline that an analysis of (internal) issue life-cycle dynamics should be complemented with an analysis of broader contexts and field-level developments. This stresses the appropriateness of studying the co-evolution of issues, industries and technologies based in a dialectic issue life-cycle model with an embedded view of industries.

V.5.2.2. Regime inertia and technology development

An analysis of the industry regime provides deeper explanations of inertia and industry resistance regarding technology strategies. In the first and second period, the industry positioning strategy, rooted in their subjective elements (beliefs about consumer demands, interpretations of market forces, economically-oriented mission), negatively contributed to the issue of air pollution, because carmakers focused on the production and sale of big cars. The favourable market scenario (increasing demand, high market shares) also meant that the industry paid little attention to institutional pressures connected to the issue of air pollution, allowing it to stay within its zone of indifference. In this context, no specific technology had to be developed in response to air pollution.

In the third period, the main source of inertia, which prevented technology development, was the technical element of the industry regime (as suggested in the DILC-model): the industry preferred to follow an incremental pathway to emission control, because it did not have competencies needed for catalyst technology. Thus, it was unwilling to certify and warrant cars with a technology external to the industry regime. In the fourth period, inertia regarding technological developments was less pronounced, but for part of the industry (Ford and Chrysler) it was still rooted in the technical element. Conversely, GM's escaped lock in by opening up its own technical regime to include new capabilities in organic chemistry that allowed the firm to develop an in-house emission control system with catalytic converter. GM thus experienced a steeper learning curve, while Ford and Chrysler contributed to the transformation of the industry regime's technical element in the fifth period, when they, too, adopted the three-way catalytic converter solution.

V.5.2.3. Changes in regime elements

The issue life-cycle process therefore did not lead to full *strategic reorientation*, as in the conceptual issue-life cycle proposed by the DILC-model. Despite the achievements in controlling emissions and addressing local air pollution, the industry continued to resist environmentalism, which was not included in its *mission*. The industry's *belief system* remained unchanged; namely, that 'environmental innovations do not sell but increase costs'. The *technical knowledge base* was altered through the incorporation of new competencies (in catalysts and electronic controls), and the technology forcing policies stimulated the American automakers to reengage with innovation, which received more strategic attention (Abernathy and Clark, 1983; Yates, 1983; Flink, 1990). The technical changes were forced by law (changes in *industry specific regulations*) and spurred by external and internal competition. Therefore, competition alone did not drive the changes in the technical element to address the societal issue.

V.6. CONCLUDING REMARKS

V.6.1. Evaluation of the mixed-methods approach

In this case study, I employed an experimental visual analysis method to divide the whole period of interest into sub-periods. The method seems particularly appropriate for the study of the air pollution issue-life cycle, because a vast amount of secondary sources was available, so that the visual analysis could be cross-checked with qualitative inputs. I was therefore able to triangulate the visual analysis with qualitative knowledge of key events in the case.

The visual analysis of attention indicators provides a useful 'first approach' to the case, and helped establish initial patterns and relationships that were later confirmed in the case study. Therefore, quantitative attention indicators seem to reveal some of the qualitative issue life-cycle relationships. The combined analysis of quantitative indicators for issue-attention and of qualitative material thus revealed that the dynamics of attention is closely connected to issue life-cycle dynamics. On the one hand, attention advocacy (by activists and scientists, social movements, the media etc.) plays an important role in driving the issue forward. On the other, factors usurping attention from the focal issue (such as competing issues) play a role in delaying the issue life-cycle.

To my best knowledge, the systematic use of attention indicators represent a contribution in measuring issue life-cycles, thus helping to address the methodological gap in issue life-cycle theory that I identified in Chapter II. The experimental method also threw light into the relationship between issue-attention cycles and issue life-cycles. As the air pollution case seems to have followed a 'normal' trajectory (even though it did not reach 'phase 5' in the period of interest), a question that remains open is whether attention indicators are also useful measures for other types of trajectories (cyclical, recurring etc.). Another question still open is how technology hype-cycles influence issue life-cycles. These open issues will be tackled in cases 2 and 3, respectively.

V.6.2. Implications for thesis' research focus and questions

The case study revealed important insights into how, when, and why incumbent industries change their strategies (the technological one, in particular) to address a societal problem. The DILC-model's basic pattern has been confirmed by the case: in early phases, industry actors formed a closed front (through APF and AMA), and employed defensive (mostly socio-cultural and political) strategies to protect the existing regime. As institutional pressures accumulated, industry actors gradually moved towards incremental technical innovation and some defensive hedging (exploration of alternatives).

A shift towards more pro-active strategies did not happen until the fourth period (phase 4), when several developments aligned: (a) tough regulations (1970 CAA), backed up by civil society pressure, changed the industry's frame conditions, (b) regime outsiders (catalyst suppliers) and new entrants (foreign competitors such as Honda and Mazda) exerted competitive pressures on industry incumbents and provided information that helped reduce the information asymmetry between regulators and the industry, (c) the closed industry-front began to crumble as individual firms adopted pro-active innovation strategies (GM acting as product champion for catalysts). The industry front closed again in the fifth period, when American car firms experienced serious economic problems, counter-mobilized and articulated an anti-regulation coalition around an economic discourse.

The case study thus raises two important insights for this thesis' research focus:

1. An important way through which industries respond to issues is by using collective strategies. The opening up and closing down of an industry fronts appear to be a crucial mechanism in issue life-cycles. In other words, collective industry strategies are an important mechanism in accelerating or delaying the progression of an issue.

2. Strategies do not remain strictly separated, but are fuzzier in the real-world. In particular, there were frequent spillovers between the industry's innovation activities and political strategies, e.g. signalling that regulations were not necessary, because firms are already working on solutions.

In this sense, the case shows the usefulness of building a new model of issue evolution that draws on issue life-cycle theory and combines insights from technology and innovation policy studies and Organizational Institutionalism. The latter point also highlights the importance of qualifying the distinction between symbolic and substantive strategies, a point to which I shall return in this thesis' conclusion.

VI. AUTOMOBILE SAFETY AND THE AMERICAN AUTOMOBILE INDUSTRY (1900-2000)

VI.1. INTRODUCTION

This second case study[94] investigates the automobile safety issue life-cycle in the United States, from 1900 to 2000. The issue represented an important and *long-lasting* challenge to the American society. To put the issue in perspective, the number of car-related fatalities in the US can be compared with the number of deaths of American military in war combats: car-related fatalities took as much as 169,700 lives between 1941 and 1946 – despite tyre and fuel rationing policies and the interruption of production of cars for civil use (USDOT/FHWA, 2010); in the same period, the number of casualties of Americans in WWII combats reached 291,557 (Leland and Oboroceanu, 2010). During the period of the Korea War (1950-1953) and the Vietnam Conflict (1964-1973), automobile-fatalities amounted to 140,773 and 522,412 cases, respectively, while combat causalities were 33,739 and 47,434, respectively. In fact, by the end of the Korean War, car-related fatalities had already surpassed the number of deaths in all wars the United States took part in since 1775 (*both* during combats and otherwise).

The absolute number of automobile-related fatalities (Figure VI.1) increased steadily in the first half of the twentieth century, with brief interruptions during the depression years (1930s) and World War II. After the 1950s, automobile-related fatalities increased sharply, reaching a peak of 55,600 cases in 1972, but subsequently followed a downward trajectory (with oscillations). The number of fatalities seems correlated with miles travelled per registered vehicle[95], particularly between 1920 and 1972[96]. But from 1972 onwards the two indicators go in opposite

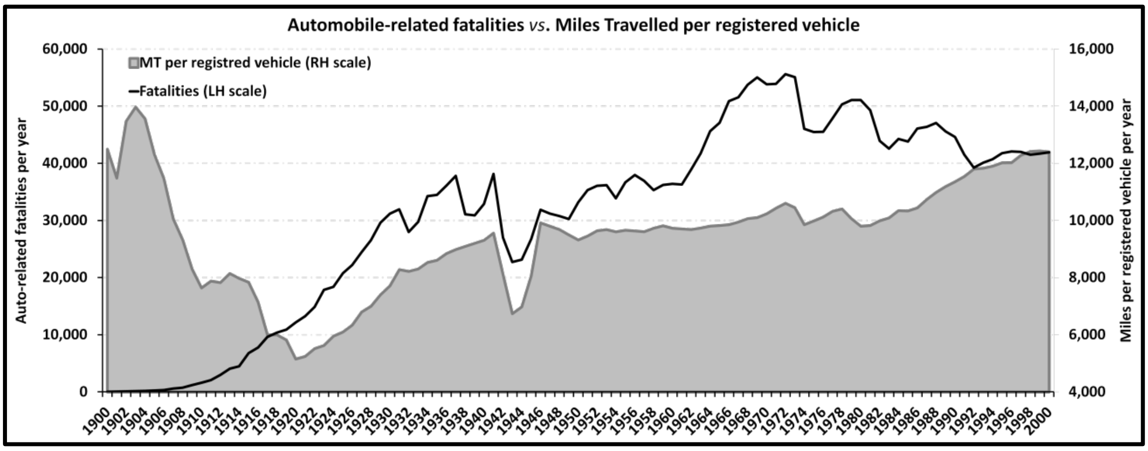
[94] A shorter version of this case study appears in Geels and Penna (2013), which is currently under (the second round of) review for publication in *Research Policy*. As in the air pollution case study, I use part of that material in this Chapter, but the present case study differs and goes beyond the article's case study, drawing on more sources and highlighting additional evidence for the analysis. Moreover, this Chapter is based on the original version submitted to Research Policy, analysing the case up to 2000 (the second submitted version ends in 1995). Finally, I use a different set of car-safety related patents for the quantification approach. These differences led me to a somehow different pattern-matching analysis, so that I indicate the differences in footnotes (wherever appropriate).

[95] In turn, sharp declines in miles travelled per registered vehicle are associated with economic crises and WWII.

[96] In fact, Spearman's rho correlation coefficient between fatalities and miles travelled per vehicle between 1920 and 1972 is 0.8850, which is significant at the 0.01 level.

directions. So, in the 1960s/1970s[97] a turning point happened in the trajectory of automobile-related fatalities.

Figure VI.1: Automobile-related fatalities and car diffusion in the United States



Source: Based on data from USDOT/FHWA (2010) (fatalities) and USDOT/FHWA (2011) (VMT and registrations)

The American car industry long denied the influence of car design on fatalities, blaming drivers or road conditions instead (Eastman, 1984). It also strongly held a belief that there was no effective consumer demand for safety items (captured in the motto 'safety doesn't sell'). But the industry gradually changed its position, initially reluctantly under pressure from public opinion and regulation (1960s), but more wholeheartedly when safety became part of consumer preferences (mid-1980s). I bound the case study with an endpoint in the year 2000, not because the problem was 'solved' (cf. Figure VI.1: car crashes were still taking about 40,000 American lives per year), but because *by then the industry had reoriented* and included safety in its mission, beliefs ('safety sells'), and innovation strategy.

This case is more complex than the air pollution one. Firstly, public attention for air pollution followed a relatively unique 'up-and-down' curve that peaked in 1970 and led to the *Clean Air Act*, which forced introduction of catalytic converters years later. Public debates on auto-safety not only showed more 'ups-and-downs' in an upward trajectory (Figure IV.3, p. 126), but also entailed changes in the way the problem was framed: initially, it was seen as a matter of driver's education, but latter, the problem received a technical framing (as a matter of redesigning the car for crash-worthiness and crash-protection). I therefore expect the car-safety issue life-cycle to follow a more complicated path than air pollution,

[97] If one calculates the rate of fatalities per miles travelled per registered vehicle, then the peak happens in 1969 (and not 1970).

possibly with recursive/cyclical patterns (Bigelow *et al.*, 1993) – this was indeed a key rationale in selecting this case.

Secondly, safety required redesign of more car components, both to help the driver to avoid crashes (e.g. breaks, steering system, windshields etc.) and to protect the driver and passengers in case they happen (e.g. seatbelts, airbags, crumble-zones etc.). Thirdly, as shown in Chapter V, demand for 'low-emission cars' never materialized during the air pollution issue life-cycle. Safety, in contrast, eventually spilled over from the institutional to the task environment, becoming a key criterion for car purchase decisions (consumer preferences); thus, the resulting market demand stimulated automakers to fully embrace safety innovations. The safety case therefore followed the 'changes in consumer preferences' route.

In summary, the characteristics of this case allows me, firstly, to investigate the factors and mechanisms through which a societal issue or challenge spills over to consumer preferences. Secondly, because the issue initially received a behavioural framing and only later a technical one, the case will allow me to investigate how different problem framings influence an issue life-cycle and lead or not to the development of distinctive solutions. In other words, in this case I will look at the co-evolution between societal problems and technical solutions: how processes underlying problem-related pressures lead to the development (or not) of technical solutions by the incumbent industry. Thirdly, as the car-safety issue life-cycle appears to be more complicated than the air pollution issue life-cycle, it can potentially reveal which factors and mechanisms influence the path an issue takes and make it deviate from the 'normal' phase-based DILC-model. I shall return to these three points in the analysis section.

VI.2. DATA SOURCES & DATA COLLECTION PROCEDURES

Like the local air pollution case study, this historical case study of car safety and the responses of the American car industry is not intended to unveil new historical evidence, but to further test the DILC-model and to generate insights for additional conceptualization based on case idiosyncrasies. I therefore draw on primary sources for quantitative indicators, while the qualitative case study is a triangulation of primary and secondary sources.

VI.2.1. Sources for quantitative indicators and data collection procedures

In this case study, I will apply two quantification approaches: the exploratory visual examination of attention indicator charts and the meta-analysis of correlations. While in the air pollution case study I used just the 'interpretive' quantification method to generate insights about broad patterns and apparent relationships between (indicators of) attention, in this case study I will use a more sophisticated method – the meta-analysis of correlations – to generate first insights about patterns and relationships. Indeed, the exploratory visual examination will be triangulated with qualitative knowledge of key events throughout the car safety issue life-cycle to establish relevant break points (for the 'temporal bracketing' into sub-periods) to be used in the meta-analysis of correlations, and, later, in the qualitative in-depth narrative.

In this case, I will use the following attention indicators:[98]

1) *Public attention:* Like in the air pollution case, as a proxy indicator of public attention, I use the number of articles on automobile safety in mass-circulation newspapers: *Chicago Tribune* (CT), *Los Angeles Times* (LAT), *New York Times* (NYT), *Washington Post* (WP) and *Wall Street Journal (WSJ)*. I used the same data collection method as in the first case study: a keyword search in each newspaper's historical archive, using the expressions "auto safety" and "highway safety" (with the Boolean operator 'OR'[99]), two of the most common ways to which the issue was referred in the United States[100]. Figure VI.2.a plots the average number of articles published by the five newspapers per year. This indicator's caveat of not accounting for changes in meaning (framing) of the problem is rather important in this case, so that I will pay particular attention to this in the narrative approach[101].

[98] As in the air pollution case study, I also look at primary quantitative data other than attention indicators, which were collected from governmental sources (e.g. the US *Department of Transportation*) and industry journals and databases (e.g. *Ward's*; *Automotive News*).
[99] Or equivalent strategies, depending on which operators were available for each database.
[100] Other combinations of words and expressions were tested, but the added value was little compared to the use of these two expressions (i.e. more words/expressions did not result in more relevant articles but increased the number of irrelevant articles).
[101] I also looked for particular expressions that reflect the different framings in the *New York Times* and collected the number of articles using these expressions over the decades. I will however draw on the resulting chart only in the qualitative analysis.

2) *Political (Congressional and Regulatory) attention:* For congressional attention, I searched the *Congressional Record* (using the *HeinOnline* database) with a set of auto-safety-related keywords.[102] The political attention chart plots the yearly number of relevant publications (outcomes of public hearings, bills proposals, reports). For regulatory attention (implementation activity), I searched[103] the *Federal Register* (*HeinOnline* database) for the number of publications per year by executive agencies. These indicators do not address content and meanings (to be analysed through the narrative), but does indicate the evolving attention to the issue.
3) *Industry 'attention'/technology development:* In this case study, I adopted two strategies for collecting car safety-related patents. A class-based search in the USPTO[104] and a keyword search in *Google Patents*[105]. This was necessary for two reasons: (1) in order to investigate the development of different types of 'solutions' according to the patents in different classes (related to e.g. accident avoidance or passenger protection or airbags or seatbelts etc.); however, (2) because the case covers a period beyond which it is possible to search the USPTO for assignees and filing date, I used the strategy of searching for car safety-related patents in *Google Patents* and ordering the set according to assignee name and filing year. The *Google Patents* search dataset may be seen as a subset of the USPTO class search (the class-based search is in

[102] After testing different combinations of words and expressions, I used the following Boolean search string to maximize the return of relevant results: "auto safety" OR "highway safety" OR "traffic safety" OR "motor vehicle safety" OR "automobile safety".
[103] Same Boolean string as in the *Congressional Record* search.
[104] The classes were: 180/268 to 180/290 ("Motor Vehicles/Safety promoting means"); 180/232 ("Motor Vehicles/Collision, protecting occupant or Motor from"); 180/268 to 180/270 ("Motor Vehicles /Safety belt or harness, Motor vehicle system responsive"); 280/801.1 to 280/808 ("Land Vehicles/ Safety belt or harness, Passive"); 280/278.1 to 280/728.3 and 280/729 to 280/743.2 ("Land Vehicles/Air bag passenger restraints"); and 280/748, 280/750 to 280/752, 280/756, and 280/757 ("Land Vehicles/Passenger safety guards").
[105] The following search string was used: collision OR accident OR crash OR safety OR occupant-restraint OR passenger-restraint OR occupant-protection OR passenger-protection OR passenger-safety OR occupant-safety OR crashworthiness OR crash-protection automobile OR motor-vehicle OR highway. Because some of the terms are very general, I restricted the search to the biggest American and foreign automakers (and subsidiaries/associated companies) and suppliers (namely, General Motors, Ford, Chrysler, Mercedes, BMW, Volvo, Volkswagen, Toyota, Honda, Nissan, Kaiser Motors, Tucker Corporation, Eaton Corporation, Autoliv, NSK, Breed Corporation, Key Safety Systems, TRW, Takata, Petri, Bosch, Bayern, Denso/ Nippondenso, and Morton-Thiokol)

fact a 'census' – *all* patents in those classes were counted). In the quantification approach, however, I will use only the *Google Patents* dataset, because (a) it is ordered by filing year and thus presents less 'lag' (in relation to the actual 'invention year'); and (b) it allows me to gain insights into the response by the American car industry (Big Three) and by the outsiders. The USPTO set will allow me to gain insight into the types of technologies being developed throughout the safety issue life-cycle (i.e. into the co-evolution of solutions and problems), and will be referred to in the narrative approach.

VI.2.2. Sources for the qualitative case study (narrative)

The qualitative case study provides a longitudinal analysis of the co-evolution of the auto-safety problem and car industry responses. The case study draws on primary and secondary sources. Primary sources for public protests and discursive framings are articles from newspapers and magazines[106], such as the *New York Times*, *Wall Street Journal, Newsweek*, *Popular Science*, and *Popular Mechanics*, and newspaper cartoons by Herblock (Johnson and Katz, 2009). For industry views, I draw on industry journals (e.g. *Ward's*; *Automotive News*) and statements in the media, and look at advertisements with 'safety' as primary or secondary theme, which I collected from an archive search in *Life* magazine (and others for more recent years); from Stevenson (2008), who analysed the American car industry advertising strategy from 1930 to 1980; and from the *Old Car Advertisements* database (www.oldcaradvertising.com), which makes available a vast collection of printed ads from American automakers from 1903 to 1989.

The case study narrative also triangulates secondary accounts that address different dimensions of auto-safety: legal and political dimensions (Miller, 1988; Weingroff and Seabron, 2003); public criticisms and discursive (framing) struggles from a historical perspective (Eastman, 1981; Eastman, 1984; Bollier and Claybrook, 1986); medical perspective (MacLennan, 1988; Waller, 2002); insurance industry perspective (O'Neill, 2009); car safety technologies, particularly seatbelt and airbag (Struble, 1998; Waters *et al.*, 1998; Nilsson *et al.*, 2003; Strother *et al.*, 2003;

[106] While newspaper and magazine articles may be considered also a type of secondary source, I attempt not to draw on the opinions of the authors (journalists), but on facts and quotes of stakeholders that the authors report.

Leonardi, 2010); organizational, advertising and corporate strategies in response to the safety issue (Nader, 1965; O'Connell and Myers, 1966; Schnapp, 1979; Davidson, 1983; Abeles, 2004; Albaum, 2005; Gerard and Lave, 2007; Stevenson, 2008). For broader industry developments impacting on the safety issue life-cycle, I draw on the same sources as in the air pollution narrative. My case study will develop a comprehensive multi-dimensional analysis through the triangulation of insights from these works.

VI.3. QUANTIFICATION APPROACH: ANALYSIS OF ATTENTION INDICATORS

VI.3.1. Exploratory visual examination

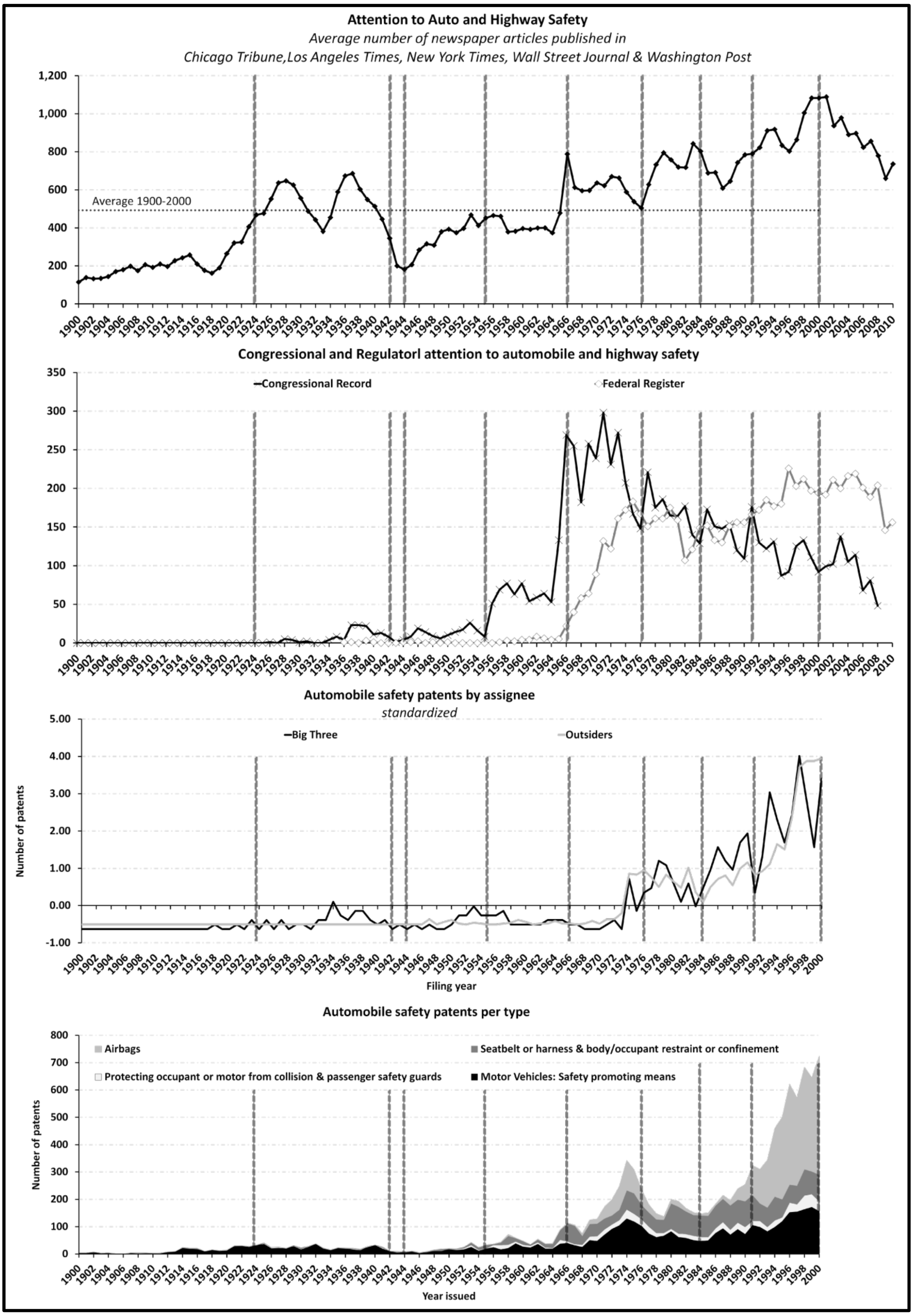
Figure VI.2 plots the indicators of attention to car safety in the US over time: (a) public attention; (b) congressional attention and regulatory (executive) attention; (c) car safety-related patents by assignee type (incumbents/Big Three and outsiders); and (d) car-safety patents by type. The visual examination will look at the first three charts, while the fourth will be explored in the narrative. The analysis is triangulated with key events in the auto safety case in America in order to arrive at the sub-periods:

a) Car safety received increasing levels of public attention in the first decades of the 1900s (Figure VI.2.a), but the issue was reported in *local* news sections (Eastman, 1984). After the First World War, public attention to car safety increased fast, possibly reflecting the rapid increase in fatalities that accompanied automobile diffusion (Figure VI.1). In the late 1920s, attention declined, possibly due to the competing issue of economic depression. But it increased again when fatalities reached record levels in the 1930s. World War II diverted automobile production to the military effort and led to rationing of rubber (tyre) and fuel, so that the issue life-cycle halted between 1941 and 1946, which is reflected both in the level of automobile-related fatalities and of public attention to it. In the 1950s, public attention increased again, but remained at moderate levels, until it rose sharply in the 1960s. In fact, the post-WWII saw the emergence of the technical framing to the issue (Eastman, 1984). Indeed, the way the issue was framed is reflected in the words used in association to the problem: Figure VI.3 shows how the use of 'reckless driver/driving' was more common up to the 1950s, while technological terms such as 'seatbelt' and 'airbag' began to be referred to more prominently from the 1960s onwards ('airbag' was particularly focused by the media in the 1990s, due to a controversy regarding hazard to children). The year of 1966 – when the *National Traffic and Motor Vehicle Safety Act (NTMVSA)* was enacted – represents a local peak in public attention. Although it declined sharply immediately after the passage of this strong piece of regulation, which mandated safety innovations, public attention returned to a trajectory of ups-and-downs from 1976 onwards. Only after the year 2000 – when I finish this case study – public attention declined again, and to pre-1970s levels.

b) Congressional attention (Figure VI.2.b) to car safety shows some oscillations at very low levels in the late 1920s and, at relatively higher level, in the 1930s. In this period, policy-makers, including the President[107], promoted car safety conferences and sponsored research on the problem. Congressional attention declined during WWII, and then returned to 1930s' levels until mid-1950s, when the new technical framing began to be voiced by professional activists (engineers and medical doctors). A great surge in Congressional activity appears in the 1960s, which seems connected with the same surge in public attention. Thereafter, Congressional attention oscillates in a *downward* trajectory, therefore contrary to public attention. Executive or Regulatory attention (Figure VI.2.b) only shows significant increase after 1966, as the implementation of the NTMVSA was delegated to a new agency: the NHTSA (National Highway Traffic Safety Agency). Implementation activity by NHTSA increased steeply and remained high after 1970 (because of implementation struggles between NHTSA and the car industry). Public attention seems to reflect these struggles, and this association will be tested in the correlation analysis.

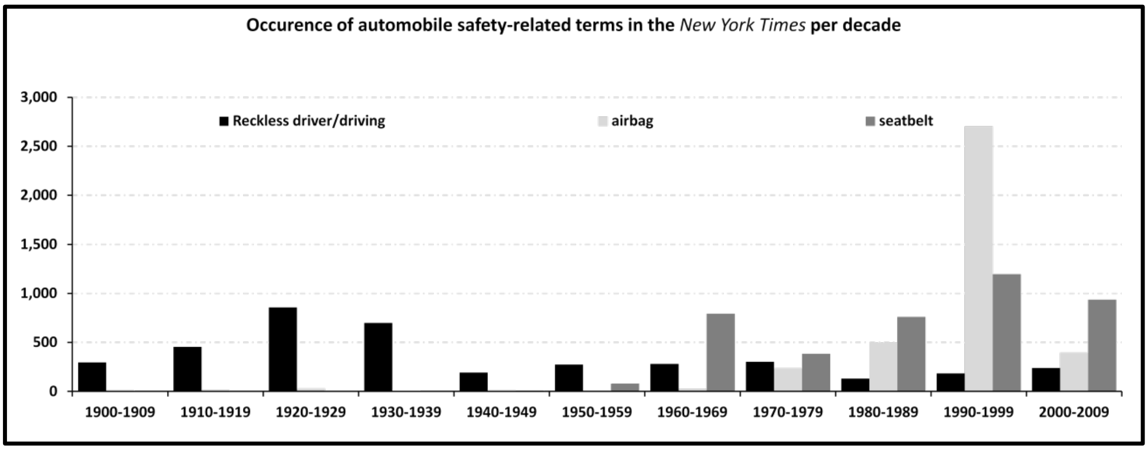
[107] The *Federal Record* only started being published in 1936, so there is no indicator for executive attention for the 1920s.

Figure VI.2 (a-d, top-down): Attention to automobile and highway safety



Source: *Author's construction (see section VI.2.1 for data sources and data collection procedures).*

Figure VI.3: The usage of terms associated to car safety over the decades reflected different problem framings and solutions



Source: Author's construction based on keyword search in the *ProQuest* database.

c) Incumbent industry attention to safety technologies (Big Three patents) (Figure VI.2.c) shows oscillations in the mid-1930s (when Chrysler 'flirted' with safety – crash avoidance – features and aerodynamic designs) and the 1950s (when Ford attempted to position in the market new models with safety – passenger crash-protection – features, and GM carried in-house R&D on car-safety). Big Three patenting only shows significant increase after implementation of the NTMVSA began in late-1960s/1970s. In the mid-1980s, when the issue spilled over to consumer preferences, we see a surge in patenting by the Big Three, which may indicate an innovation race. The Google Patents dataset show outsiders relatively inactive before the 1960s[108], although in the late 1940s there is some patenting activity (associated with the initiative of Tucker Corporation and Kaiser Motors to design cars with safety – crash-avoidance and passenger protection – features). And, in the late 1960s, outsiders seem relatively more active than regime actors, albeit at a low level. From the mid-1980s onward, we see a steep upward trajectory in outsiders' patenting, reinforcing the idea of an innovation race.

Based on this visual analysis complemented with qualitative knowledge[109], I propose the following sub-division of the 1900-2000 period:

[108] The relative inactivity of outsiders indicated by this dataset may be deceptive, given the amount of patents found with USPTO class-based search. This might be due to restricting the search to a small (but important) number of outside firms (a closer look – random scanning – at the patents in the USPTO set shows however many inventions by individuals in the pre-1960s era).
[109] Alternative periodization based on a visual analysis is possible, particularly for the first two periods. This point emphasizes an important caveat of the visual analysis, which is based on a subjective interpretation. To 'test' for robustness, I experimented with an alternative

1. 1900-1924: emerging public attention and concern;
2. 1924-1942: rising public attention, with some political and industry activity;
3. 1942-1946: disruption by Second World War;
4. 1946-1955: relatively low public attention but moderate Congressional attention;
5. 1955-1966: substantially increasing public and political attention, culminating in the 1966 peak;
6. 1966-1976: substantial increase in implementation activity (decreasing Congressional attention) and in incumbent industry technology development;
7. 1976-1984: decreasing regulatory activity and industry innovation (implementation controversies);
8. 1984-1991[110]: end of regulatory uncertainty and increasing patenting activity, with innovation race between incumbents and outsiders around airbag technology;
9. 1991-2000: emerging market for safety innovations further accelerating patenting activity.

So, the case appears to have more 'phases' than in the 'normal' pathway of the DILC-model. Have any of the ideal-type phases been repeated during the car safety issue life-cycle? If so, what pathway did it follow? The qualitative case study will attempt to address these questions. Before I turn to it, the next section will look for initial insights about relationships by applying the method of meta-analysis of correlations within this 'temporal bracketing' framework.

VI.3.2. Meta-analysis of correlations within a temporal bracketing framework

The meta-analysis of correlations should be treated with care, particularly since some sub-periods are rather short. I therefore take a conservative approach in this analysis. As explained in the methodological Chapter (section IV.2.2.2), I use

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periodization (dividing the period between 1900 and 1942 into three sub-periods), but concluded that two sub-periods were more appropriate, because core dynamics and process did not differ substantially between the alternate three sub-periods (see case study narrative). Robustness of the periodization based on visual analysis will be objectively tested in the third case study (Chapter VII), which will also make use of the statistical test for unknown structural breaks.

[110] This is the final period analysed in Geels and Penna (2013), which however ends in 1995.

Spearman's rho correlation coefficient (instead of the more common Pearson's correlation coefficient), which is more appropriate for non-parametric/non-normally distributed data and for smaller samples (Gibbons and Chakraborti, 2003). Moreover, I will adopt a conservative confidence interval and mostly focus on strong (> 0.80) correlations that are significant at the 1% level. One may interpret Spearman's correlation as following: if, for example, public and political attention are strongly correlated, it means that, in a given period, years of high (low) public attention are associated with years of high (low) political attention.

Although I adopt an overlapping sub-periodization, for the correlation analysis I consider the final year of a period as part of the precedent period (e.g. the period 1955-1966, identified above, is composed of 11 observations, not including 1955 but including 1966). The correlation analysis reveals interesting associations (the reader is referred to Appendix I.1 for the complete set of results):

- *Associations during first sub-period [1900-1924]:* In the first sub-period, the only significant and strong correlation (0.8159) is between public attention and fatalities, implying that the media/public is attentive to the 'objective' side of the issue. This is less trivial and obvious than it appears: proponents of issue-attention cycle argue that "an issue may rise and fall more or less independently of the factual development of the publicly perceived problem or whether it is politically 'solved' or not" (Newig, 2004, p. 151). Yet, it seems to indicate that the objective side of the issue matters, at least during early phases of the issue life-cycle.
- *Associations during the second sub-period [1925-1942]:* In the second sub-period, the correlation analysis did not capture any significant correlation at the 1% level. (At the 5% level, however, Congressional attention is medially correlated to fatalities (0.5654), which could indicate that policy-makers began to engage in (maybe symbolic) action.) Although this lack of associations is possibly due to methodological issues, it could also be indicative of a period when many issues were competing for attention from all actors (e.g. Great Depression, arms race before WWII, labour and market issues etc.).
- *Associations during third sub-period, the WWII break [1943-1946]:* This period comprises too few observations for a meaningful correlation analysis.

- *Associations during fourth sub-period [1947-1955]:* In this period, patenting by the Big Three is significantly and strongly (0.9048) associated with fatalities (at the 5%, it is medially correlated with Public (0.7730) and Congressional (0.7321) attention). This period was characterized by increasing political debates and a (failed) attempt by Ford to break an existing 'closed industry front' with safety innovations.
- *Associations during fifth sub-period [1956-1966]:* The correlation analysis did not capture any significant correlation in this sub-period. This was a period of intense public and political debate, and this result may stem from a methodological issue.
- *Associations during sixth sub-period [1967-1976]:* After the enactment of the NTMVSA, patenting activity by outsiders became significantly and strongly (0.9268) associated with regulatory attention (implementation activities). This is in line with the notion that outsiders react first to pressures connected to a societal issue. Public attention is also strongly (0.8788) associated with fatalities, which fell after the energy crisis of 1973. (Big Three patenting is medially correlated with both outsiders' patenting (0.7038) and regulatory activity (0.6650), but just at the 5% level.)
- *Associations during seventh sub-period [1977-1984]:* The correlation analysis did not capture any significant correlation in this sub-period, except between regulatory attention and fatalities, which does not make much analytical sense. This was a period of intense implementation struggles, and this result may stem from a methodological issue.
- *Associations during eighth sub-period [1985-1991]:* Public attention becomes significantly and strongly (0.8829) associated with regulatory attention.[111] This was a period when regulatory activities resumed, and when there was a public debate over mandatory 'passive safety' technologies (automatic seatbelts *vs.* airbags); the public/media seems therefore attentive to these developments.
- *Associations during ninth sub-period [1991-2000]:* In the final sub-period, the correlation analysis did not capture any significant correlation at the 1% level. (At the 5% level, however, outsiders' patenting is medially (0.7017) correlated to

[111] Big Three patenting is significantly but *negatively* correlated to Congressional attention, which can be interpreted as patenting increasing despite the decrease in policy-making activity.

public attention.) This was a period of controversy over airbag safety for children, and outsiders might have been reacting to pressures for safer airbags.

- To test the notion that an innovation race started after 1984, I also carried out a correlation analysis for the *period [1985-2000]:* Indeed, the analysis shows a significant and mid-strong (0.7795) correlation between Big Three patenting and outsiders patenting.[112]

Even though I am using Spearman's rho, which is a more powerful correlation test for small samples, many sub-periods are *very* short (few observations), so the correlation analysis revealed problematic and these findings should be treated with *extreme* care (i.e., not definitive). Yet, the basic correlations *suggest* some interesting patterns, some of which resonate reasonably well with the DILC-model: (a) public attention appears reactive to the objective side of the issue in early periods (which indicates phases 1 and 2), but later tends to correlate with political and regulatory attention (phase 3 and 4); (b) some political attention is also attracted to the objective side of the issue in early periods (phase 2); (c) outsider's seem to react first to the prospects and the actual enactment of substantive pieces of legislation (phases 3 and 4); and (d) innovation race takes place towards the end of the issue life-cycle, when the issue is spilling over to the task environment (phases 4 and 5).

However, the analysis also showed incumbents reacting to the issue in terms of technological development maybe earlier than expected (1946-1955), given that the issue was interrupted by WWII. This is a puzzle to be analysed qualitatively. More importantly, the correlation analysis did not capture associations during some of the periods (in section VI.6 I will critically evaluate the method). These insights should not be treated as definitive: to qualitatively investigate patterns and mechanisms in the car-safety issue life-cycle, I now turn to an in-depth narrative-based case study.

VI.4. QUALITATIVE APPROACH: IN-DEPTH NARRATIVE

Following the case study protocol, for each period I describe: (1) problem-related pressures (from activists; social movements; public opinion; policy-makers;

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[112] Outsiders' patenting is strongly correlated with both public and regulatory attention (0.8800 and 0.8660, respectively). Both levels of attention are indeed correlated (0.8277).

suppliers; competitors; regime outsiders etc.); (2) response strategies from firms in the American car industry; and (3) broader developments in task or institutional environments that (positively or negatively) influenced car-safety life-cycle dynamics or industry strategies. Because this is a rather long case, to guide the reader, I introduce some analytical notion in the beginning of each period, anticipating matches and deviations with phases from the DILC-model.

VI.4.1. Issue emergence and sense-making (1900-1924)

The rapid expansion of car numbers (from 8,000 in 1900 to 23 million in 1930) was accompanied by rising fatalities, from 36 in 1900, 1,599 in 1910, to 12,155 in 1920 (Figure VI.1). Public concerns led to sense-making activities – the main process at work in the period, which fits well with phase 1 of the DILC-model. The 3E-framing became the dominant problem definition, emphasizing driver *Education*, law *Enforcement*, and road *Engineering*. The empirical period deviates in some respects from phase 1: (a) there was no indication of a framing struggle through denial strategies, because (b) the industry *accepted* the 3E-approach, which posed no real threat to its identity. The transition to the next period entailed the formation of an organized safety movement, but around a particular framing that did not make automakers accountable for the issue.

VI.4.1.1. Pressures around issue

Social movements and public opinion. Car accidents (Figure VI.4) were commonly featured in local news sections of newspapers, which, together with influential periodicals (*Scientific American, American Agriculturist*) raised auto-safety as a public issue, expressing concerns about careless driving and speeding (Eastman, 1984). The *National Safety Council* (NSC), created in 1913, included highway accidents in its remit a couple of years later (NSC, 1995). Because the criticisms threatened the legitimacy of cars, automobile clubs lobbied policy-makers for legislation that would legally embed cars in society (Rao, 2004).

Figure VI.4: Accident on a winter day in Washington, D.C., circa 1920 (despite material damage – to the vehicle, a mailbox, an emergency call box and a lamppost – no human casualty was registered)

Source: National Photo Co., available at http://www.shorpy.com/node/6957, downloaded on: Jan. 31st, 2011

Policy-makers. Public authorities introduced various regulations to embed the car in society (Geels, 2005). Car registration and car tags facilitated identification in case of accidents. States established driver's licenses, speed limits, and traffic police. But regulations were not uniform and often symbolic (Rao, 2004). Road expansion programmes led engineers to focus on the influence of road design in accidents. In 1915, a safety activist (Julian Harvey) coined the 'triple E' (3E) slogan that came to dominate the public framing of road and auto safety (MacLennan, 1988). This 3E-framing became "almost universally held by the public, private safety organizations and government" (Eastman, 1984, p. 127). The framing was in fact a result of common sense: because the car was an inanimate object, the blame for causing an accident was on the driver.[113] Moreover, the word 'accident' also implied it was a chance occurrence. The technical design of cars was not included in this early problem framing, which thus posed no threat to the shared industry identity.

[113] This is similar to the gun lobby claim and framing that 'guns do not kill people; people kill people' (I thank Prof. Ben Martin for this insight).

VI.4.1.2. Car industry issue responses

Socio-cultural and political strategies. Because the car industry was interested in a safe environment for cars, it created the *Safety First Committee* (1916), which became the *Traffic Planning and Safety Committee* in the early 1920s (Luger, 2000). This committee supported the 3E-framing, arguing that people – not cars – caused accidents. Because accidents were 'abnormal events', they saw no obligation to design cars for this 'unlikely circumstance' (Eastman, 1984). Trade journals emphasized driver's responsibility for accidents, using metaphors such as 'the reckless driver' or 'the nut behind the wheel' (Nader, 1965), terms also adopted by the mass media (Figure VI.3). The committee therefore only supported educational efforts (including to children, 'drivers of the future') and information campaigns based on slogans. So, the main type of industry response was through public relations strategies. Safety was mainly absent from marketing strategies (Stevenson, 2008).

VI.4.1.3. Influences of broader industry contexts on issue life-cycle

Car-related fatalities were not high on the agenda, because the emerging industry faced many other pressures (Geels, 2005), e.g. industry shake-out and cut-throat competition; the creation of dealer networks and supply chains for raw materials and components; product and process innovation (e.g. development of assembly lines and mass production methods). Exits, mergers and take-overs resulted in an oligopoly, with the 'Big Three' (Ford, General Motors and Chrysler) accounting for over 80% of the industry's output in 1930.

VI.4.2. Increasing public concerns, policy interest, and closed industry front (1924-1942)

The key processes in this period fit well with phase 2 from the DILC-model: (a) increasing public attention to auto-safety, which however only led to (b) symbolic policy action; the 1924 *National Conference on Street and Highway Safety* was "the first official [Federal] government acknowledgement that motor vehicles presented safety problems" (Luger, 2000, p. 56); (c) incremental innovations (accident-avoidance technologies) and political strategies: the car industry set up a front organization, the *Automobile Safety Foundation* (ASF), and created a closed front around the 3E-framing, which excluded reference to faulty automobile design. This period also deviated in some respects from phase 2: (a) social movements did not dramatize new scientific findings; instead, outside professionals (engineers, physicians) raised concerns about the ignored role of car design, which however (b) did not lead to a public framing struggle'; (c) tyre manufactures exerted symbolic pressure in the task environment; and (d) public and political attention declined in the mid-1930s (due to the Great Depression and as military preparations increased). The issue life-cycle came to a halt with the US entering WWII.

VI.4.2.1. Pressures around issue

Social movements and public opinion. Public attention peaked in the mid-1920s, following national conferences in 1924 and 1926, and in the mid-1930s, following a 1935 article in Reader's Digest ("... and sudden death"), which caused a "jump in public concern for the problem of vehicle safety" (Luger, 2000, p. 56). Reader's Digest received 3.5 million reprint orders by individuals, businesses, police departments, and traffic courts; by January 1936 an estimated 35 million article copies had been printed (Eastman, 1984). The article not only drew attention to rising fatalities, but also vividly described how e.g. knobs and sharp edges in dashboards caused serious injuries in car accidents (Figure VI.5). But – echoing the 3E-framing – the article advocated safe driving, not changes in automobile design.

Figure VI.5: Graphic illustrations of the 1935 *Reader's Digest* article by Herblock[114]

Source: Johnson and Katz, 2009

Science. But not everyone accepted the 3E-framing. Some professionals advanced a different understanding, drawing attention to technical car designs. Dr. Claire L. Straith, a plastic surgeon who witnessed the trauma from car accidents in her clinic, urged industry officials to redesign cars to minimize injuries in case of crashes (Eastman, 1981). Hugh DeHaven, an independent automotive engineer who pioneered crash-injury research and crash-survival engineering (Hasbrook, 1956), linked car features – windshield structures, instrument panels, etc. – to specific injuries. He therefore called for changes in the 'structural environment' (internal design) of automobiles. An editorial in *Scientific American* (1937, p. 216, *apud* Eastman, 1984) also suggested that automobile designers should go "as far as possible in making the whole interior of a motor car a safety interior". This alternative scientific understanding of auto-safety was largely ignored by established safety groups, such as the NSC, whose 3E-framing excluded car design as a contributing factor (Weingroff and Seabron, 2003).

[114] Before WWII, Herblock worked for the *Newspaper Enterprise Association*, producing syndicated cartoons that were published across the United States; he became chief editorial cartoonist for the *Washington Post* after being discharged from the army, where he served during WWII (Johnson and Katz, 2009).

Policy-makers. The federal government organized national safety conferences in 1924 and 1926, which were attended by many stakeholders (MacLennan, 1988). While expressing concern with the issue[115], the government left safety legislation to state and local governments (Eastman, 1984), and embraced the 3E-framing. The conferences paid some attention to safety features that could help the driver to *avoid* accidents (brakes, steering gears, lighting, horns), but otherwise embraced the 3E-framing and called for education, enforcement and better roads (MacLennan, 1988).

In the late 1930s, some changes appeared in the government's position. The 1936 conference, organized by President Roosevelt, deviated somewhat from the 3E-framing in its emphasis on technical design changes: "engineering – a change in the power and design of cars to protect the reckless motorist against his own folly – appears to hold out the only possible hope of solution" (quoted in Eastman, 1984, p. 145). The final report also hoped that carmakers would make changes voluntarily rather than wait for mandated design standards (O'Connell & Myers, 1966). Thus, no substantive policy outcome resulted from the conference.

Regime outsiders. While incumbents largely ignored car safety in positioning their products, tyre manufacturers, which were relatively invisible industry players (i.e. regime outsiders), adopted a more aggressive approach, because they saw public concerns as an opportunity for selling safer (and more expensive) tires. Goodyear, for instance, used 'shocking' ads to convince costumers to buy 'Lifeguard Tires' (Figure VI.6). Also *General Tires* promoted its product with reference to safety (Stevenson, 2008). This kind of 'symbolic pressure' by weak players was not enough to nudge automakers into similarly aggressive marketing approach (see below).

[115] So, politicians do seem to be reacting to the objective side of the issue, as indicated by the correlation analysis.

Figure VI.6 (a-b, left-right): 'Shocking' *Goodyear* ads to sell 'lifeguard' tires

Source: *Life* megazine, several editions from the 1930s, available at: http://books.google.com/books?id=VFEEAAAAMBAJ, accessed on Dec. 1st, 2010

VI.4.2.2. Car industry issue responses

Socio-cultural and political strategies. Automakers created the *Automobile Safety Foundation* (ASF), which "took the lead in directing the issue of traffic safety, ensuring that the industry's interests would be protected" (Luger, 2000, p. 58). The ASF offered grants for the training of policemen and traffic engineers, and for assisting existing safety organizations in their education campaigns (Eastman, 1984). The ASF advanced the 3E-framing through a seven-point programme focused on *Legislation*, *Motor Vehicle Administration*, *Enforcement*, *Engineering*, *Education*, *Technical Personnel Training*, and *Research*, which was amply promoted in mass media (Eastman, 1984). Through a continuation of the public relations approach based on slogans (Weingroff and Seabron, 2003), the ASF "deflected attention away from the dangerous characteristics of cars and trucks manufactured by the auto industry" (Farber, 2002, p. 182).

Technological innovation and positioning strategy. Safety glass was introduced because consumers worried about razor-edged glass pieces in case of accidents (Farber, 2002). GM mainly implemented 'safety features' which helped *avoid* accidents or improved the cars structure (e.g. hydraulic brakes, all-steel bodies) (cf. Figure VI.2.d – before the 1940s, most car-safety patents are classified as 'safety promoting means', not specifically for car-occupant protection, which seems to reflect the dominant framing of the early decades indicated in Figure VI.3).

While advertisements mentioned these design features, these were promoted "as a facet of generally improved design" (Stevenson, 2008, p. 189). Crashes or accidents were not mentioned, because automakers did not want to link cars to negative images that could scare consumers. The industry believed that the explicitly promotion of safety features would imply that "their absence would lead to illness, injury, or the death of the consumer's family" (Stevenson, 2008, p. 191).

Chrysler however deviated from the mainstream framing of the problem, because it was directly influenced (lobbied) by Dr. Straith, who visited Chrysler production facilities in Detroit (Eastman, 1984). It thus developed some occupant-production features, such as instrument panel controls that were set flush with the surface; protruding knobs were removed; door handles were smoothed and rounded; and the top of front-seat backs were tufted for the protection of rear seat passengers (*idem*). Again, these were not explicitly promoted as safety features but as general improvements of a new model year.

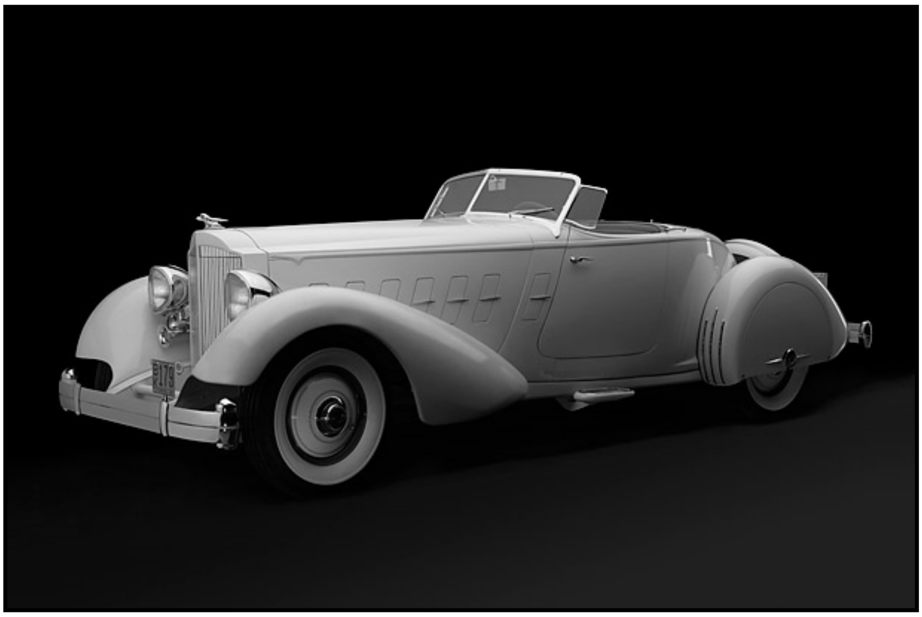
VI.4.2.3. Influences of broader industry contexts on issue life-cycle

To cope with an increasingly saturated market, automakers' attention shifted towards styling and marketing practices associated with *Sloanism:* annual model changes and planned obsolescence; consumption ladder; and consumer credit. While the first principle could be based in new generations of technologies, in fact it resulted in non-functional changes:

> *The use of technological innovation as a basis for yearly new models was rarely considered by General Motors or any other manufacturer – research was expensive, risky, unpredictable and not in the tradition of the industry; furthermore, technical developments were often difficult for the consumer to appreciate. The use of restyling, on the other hand, could easily be made to conform to a yearly cycle and a precise budget, and the modifications to be made in the product could be selected on a basis of their adaptibility to advertising.* (Eastman, 1984, p. 23)

The obsession with annual model changes resulted in implementation of styling innovations that *negatively* influenced safety (Nader, 1965). Windshield designs, for instance, were built with increasingly sharper angles ('V-type windshields') in the 1930s (Figure VI.7), which negatively influenced driver's visibility with distortion and blind spots (Eastman, 1984). The lowering of the driver's seat also created visibility problems, because the front fender was outside the driver's camp of vision (Nader, 1965; Eastman, 1984).

Figure VI.7: V-type windshield, such as in this luxurious 1934 Packard Twelve Runabout Speedster, could distort driver's vision



Source: Atlanta High Museum of Art, The Allure of the Automobile exhibition

Consumers were interested in fashionable, fast, large and powerful cars, which led the industry to focus on high performance and *speed*. In the late 1920s, the industry's advertising practices received some criticisms because they encouraged speeding (Stevenson, 2008), and thus contradicted driver education efforts. Automakers argued that it was not their fault that cars were driven too fast. They also claimed that cars that could be driven at 100MPH were so well built that they would be exceptionally safe at ordinary speeds and help drivers escape accidents (Eastman, 1984). Consumers exerted no demand for safety-related technical features, which is why firms paid limited attention to it (Gartman, 1994).

VI.4.3. Interruption by the Second World War (1942-1946)

The issue life-cycle was interrupted by the Second World War, which greatly diminished social and political pressures regarding car safety. War policies stopped civilian car production and restricted car driving through the rationing of gas and tires (Yates, 1983). To save fuel and rubber, a maximum 'Victory Speed' was set at 35 MPH. There was a marked decline in highway fatalities (Figure VI.1). In fact, all attention indicators (Figure VI.2) declined during the war. In addition, the car industry paid no attention to safety, because it became enrolled in the war effort.

The car industry came to be seen as the "keystone of the Arsenal of Democracy" (Frazier, 1942). The war effort consolidated Detroit's legitimacy and reputation before politicians and public opinion.

VI.4.4. The High-point of the safety establishment and of the 3-E framing (1946-1955)

In the post-WWII decade, highway casualties rapidly increased to pre-War levels (Figure VI.1). While public attention remained lower than in the 1920s-30s, policy-makers and the established highway safety movement, which was 'captured' by the car industry through the ASF (Nader, 1965; Eastman, 1984; Weingroff and Seabron, 2003), continued to advocate the 3E-approach to auto-safety in response to the issue. But this approach was criticized by two professional communities: (1) crash-injury researchers and crashworthiness engineers; and (2) the medical establishment. Both communities articulated an alternative problem framing that focused on car designs that limited *injuries* (in addition to the prevention of *accidents*). The articulation of a (new) problem framing by activists indicates the issue life-cycle restarted at phase 1. However, the period contains an important element of phase 2: a framing struggle, because the industry had already established an IOR, the Automobile Safety Foundation, which closed the industry-front around a framing that maintained the *status quo*. The period also contains elements from phase 3: (a) small firms (Tucker, Kaiser-Frazer) tried to open up the industry-front by publicly promoting safety innovations, which (b) resulted in defensive hedging by automakers (who established safety departments to monitor crash-injury research). And elements from phase 4: direct involvement of macro-level politicians (the President,). Overall, this appears a mixed period, but better characterized as phase 2[116], due to the emergence of the framing struggle.

VI.4.4.1. Pressures around issue

Public opinion and science. Public attention to auto-safety was relatively low (Figure VI.2.a). Pressure came primarily from two professional communities. The new field of "crash-survival design engineering" (Hasbrook, 1956) investigated the influence of car design features. The *Auto Crash Injury Research* (ACIR) project

[116] Geels and Penna (2013) interpret this as phase 4, giving prominence to the involvement of macro-level politicians.

(1948), coordinated by Hugh DeHaven in partnership with the Indiana Police Force, showed that opening doors, windshield structures, dashboard designs and steering systems caused many injuries and deaths (MacLennan, 1988). Air Force[117] Colonel Stapp started experimental crash research (using anesthetized animals or human volunteers in crash experiments) to further investigate relationships between design features and types of injury (Eastman, 1981). "In effect, [...] a new engineering field has been created, namely that of *crash-survival design engineering*" (Hasbrook, 1956, p. 273).

While the engineering community contributed with scientific findings, the medical profession was the strongest group engaged in attention advocacy, actively promoting the associated technical framing to address car safety. In the late 1940s, medical doctors (Straith, Fletcher, Sheldon) also began advocating design modifications to minimize injuries in case of crashes (Eastman, 1981). Some, like Dr. Straith, continued to directly lobby automakers. They suggested removal of all knobs, cranks, drop-down ash trays and sharp edges from dashboards; that the steering column be 'collapsible' (instead of rigid); that the windshield be hinged so that it is forced outward before breaking; installation of seatbelts as standard equipment, like they were in aircrafts (Eastman, 1984). By the mid-1950s, the *American Medical Association* and the *American College of Surgeons* began issuing official resolutions urging car manufacturers to pay more attention to automobile safety (Luger, 2000).

Policy-makers. Auto-safety received high-level political attention at the President's Highway Safety Conferences in 1946, 1949 and 1951. These conferences were dominated by automakers, traditional safety organizations (NSC, ASF), and highway and traffic engineers (Weingroff and Seabron, 2003), and reflected the 3E-framing emphasis on education, enforcement and engineering. Concerns about rising fatalities also led to the establishment of the President's *Action Committee on Traffic Safety* (1954). Although many groups (labour, media, rural associations, insurance industry, safety organizations, women's groups, public officials) became members, the committee was dominated by the car industry, which appointed and paid the executive director (Luger, 2000). This committee institutionalized the 3E-

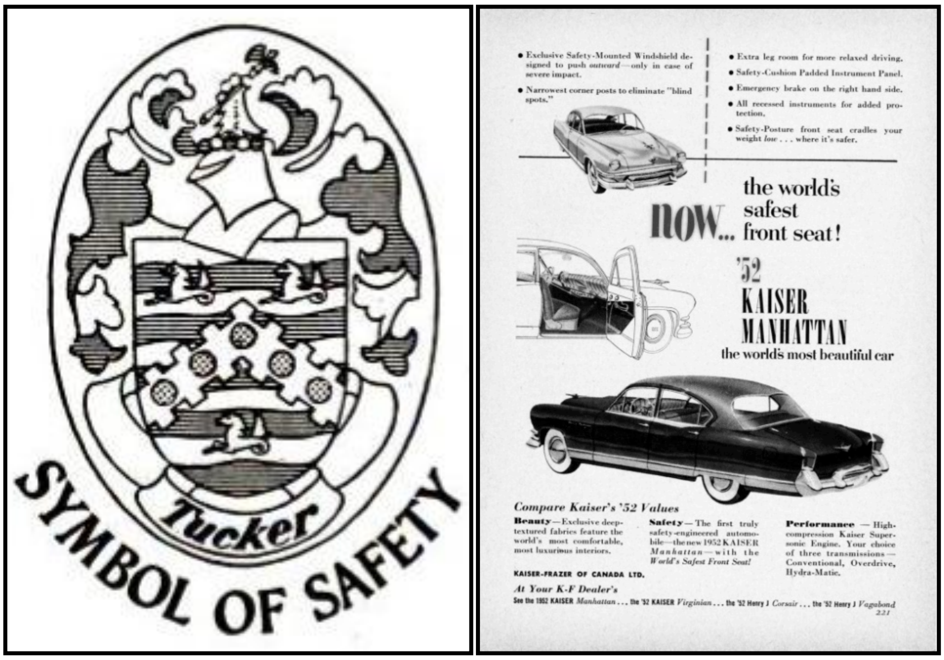
[117] The US military forces were interested in promoting means of protecting car occupants, because it lost many personnel during WWII due to motor vehicle crashes off-battle.

framing at the highest political level and "symbolized the high point of the status and significance of the safety establishment and of the automobile industry influence on the highway safety movement" (Eastman, 1984, p. 147).

New entrants and regime outsiders. Pressure in the task environment was exerted by (a) two new entrants, who were influenced by the call for safer automobiles by the professional communities, and (b) an industry regime outsider from the insurance industry.

a) In the late 1940s, Tucker Corporation, which embraced safety in its mission (Figure VI.8.a), produced a car (the 1948 'Tucker Torpedo') with safety-oriented design features. After a visit of Dr. Straith, the engineering team redesigned the door handles (to prevent opening in case of crashes) and the locations of control knobs (installed beneath the steering wheel), and added 'sponge-rubber' crash padding to the entire circumference of the interior and behind front seats (Popular Mechanics, 1947). They also made the rear-view mirrors safer by using silver-plated 'flexiglass', and mounted the safety-glass windshield so that it would break away under a 100 pounds per square inch pressure (Eastman, 1984). In the early 1950s, Kaiser-Frazer claimed to have developed the 'World's First Safety-First Car', which incorporated a crash-pad that extended throughout the instrument panel, recessed instruments, and a pop-out windshield (Stevenson, 2008). In advertisements, Kaiser claimed its cars had 'the world's safest front seat' (Figure VI.8.b).

Figure VI.8 (a-b, left-right): Tucker's logo and Kaiser's 1952MY advertisement



Source: Tucker's advertisement published in Life, vol. 24 (8), Mar 1, 1948, p. 63; and Old Car Advertisements, available at: http://www.oldcarads.ca/Kaiser-Frazer%20Ads/dirindex.html; downloaded on Dec. 6, 2010

Both companies actively advertised the safety features, which stimulated public attention, particularly from specialized publications such as *Popular Science* and *Popular Mechanics*. In the words of Popular Mechanics (1947, p. 137), the 1948 Tucker Torpedo was a "convention-defying car" that would "revolutionize the automobile industry". However, the task environment pressure soon subsided and the impact of these positioning, innovation and advertising strategies was limited (Stevenson, 2008): Tucker went bankrupt before mass producing the Torpedo, while Kaiser-Frazer never conquered much market share and in 1953 was acquired by Willys-Overland (Flink, 1990).

b) In 1951, *Liberty Mutual Insurance Company of Boston* contracted *Cornell Aeronautical Laboratory* (connected to Cornell University) "to undertake a study of how passengers moved within an automobile in a crash and the probability of their hitting objects within the vehicle which could cause an injury" (Eastman, 1981, p. 418). This initiative was significant, given that the insurance industry[118] was an historical supporter of the highway safety establishment and its 3E-approach to the auto accident problem.

[118] For the insurance industry, at stake was the payment of claims for injuries and deaths.

VI.4.4.2. *Car industry issue responses*

Socio-cultural and political strategies. The car industry supported the 3E-framing through the ASF and the NSC, which functioned as an "arm of the industry" (Luger, 2000, p. 58). The 3E-framing protected industry interests, because it kept car design off the agenda. Automakers also shaped the political (safety) agenda through lobbying and public relations: direct conversation with the President, through membership of the President's *Action Committee*, and through letters and testimonies (Weingroff and Seabron, 2003).

Technological innovation strategy. As a defensive hedging strategy, the industry began monitoring developments in crash-injury research and crashworthiness engineering (Luger, 2000). Chrysler established a safety department in 1952, followed by Ford (1955) and GM (mid-1950s). These departments enabled new *specialized* capability development, and thus represented an important organizational innovation: "for first time, major automobile manufactures' safety tests were fully conducted and analyzed not by parts technicians, but by engineers who worked to integrate the emerging theories of crash energy management into vehicle testing" (Leonardi, 2010, p. 259). However, "this did not represent a sudden transformation of the industry's thinking on vehicle design. Instead, business prudence dictated watching these developments closely" (Luger, 2000, p. 63-4). The defensive hedging strategies were to some extent spurred on by activities of the two new entrants, and by the coalescence of automotive crash engineering research into a body of knowledge. So, scientific findings compounded with pressure in the task environment seem to explain the 'puzzle' (identified through the correlation analysis) of (early) development of technologies after the WWII interruption.

VI.4.4.3. *Influences of broader industry contexts on issue life-cycle*

Consumer demand, which had been deferred during the war, showed a preference for stylish, almost extravagant, high performance cars (Yates, 1983). Safety was not a primary criterion for most car buyers (Stevenson, 2008). Automakers therefore paid more attention to price, styling, gadgetry, and horsepower than to safety. Styling innovations such as tailfins and 'wraparound' windshields actually had negative influences on safety.[119] The high-performance V8 engine developed by GM (1949), which kicked off the 1950s 'horsepower race', also negatively influenced safety, because it increased the speed at which cars could be driven (Flink, 1990). Policy-makers hardly interfered with these developments, because the car industry enjoyed high political legitimacy in the immediate post-WWII, which translated into relative autonomy (Luger, 2000).

VI.4.5. Political debates and erosion of the 3E-framing (1955-1966)

This period shows an underlying dynamic that fits with an ideal typical 'phase 3' of the DILC-model. Although public attention initially stayed at moderate levels, the dialectical framing struggle spilled over to the political debate, leading to a surge in public attention by the mid-1960s (Figure VI.2.a). The design-oriented approach to safety gathered pace and influenced policy-makers, who engaged in increasingly heated debates in investigative hearings (which also fits phase 3). The 3E-framing gradually eroded (cf. Figure VI.3). While GM engaged in defensive hedging through in-house R&D, Ford stepped ahead, and, in 1955, an early crack appeared in the industry front, when Ford used safety designs to jockey for competitive advantage. This deviates from the phase-model, which posits cracks only in phase 4. Yet, the remainder incumbent industry (GM, in particular) quickly apprehended Ford's initiative, re-closing the industry front. By the mid-1960s, industry legitimacy weakened substantially because of the so-called Ribicoff-hearings and two scandals. The related surge in public and political attention (Figure VI.2.a and Figure VI.2.b) set the stage for the 1966 auto-safety act, which adopted as official framing the design-oriented approach. The act signalled the move to the next period.

VI.4.5.1. Pressures around issue

Science, social movements and public opinion. The design-oriented framing gathered strength because of ongoing activities from the engineering and medical communities. In 1955, DeHaven patented the first three-point seatbelt system. Its effectiveness was demonstrated in experimental crash tests (Nader, 1965; Eastman,

[119] Although the 'wraparound' windshield provided a panoramic view, it created visual distortion due to prismatic effect and increased glare (Eastman, 1984). Tailfins posed risks to bystanders, particularly children (Jain, 2004).

1984). Stapp's contribution to crash research was recognized by the creation of an annual *Stapp car-crash conference,* which was embraced by the *Society of Automotive Engineers* in 1966, signalling wider recognition and institutionalization of the field (Leonardi, 2010).

The American Medical Association increasingly urged Congress to enact legislation mandating car safety standards (Eastman, 1981). Doctors campaigned for seatbelt installation (Figure VI.9), framing it as the 'medicine' that was being withheld from patients. Special issues on automobile crash injuries were published in *Clinical Orthopaedics* (1956) and the *Journal of the American Medical Association* (1957). The newly founded (1957) *Association for the Advancement of Automotive Medicine* (AAAM) organized annual scientific conferences on safety and traffic injury prevention (Eastman, 1981).

Figure VI.9: The medical community campaigned for seat-belt installation and use

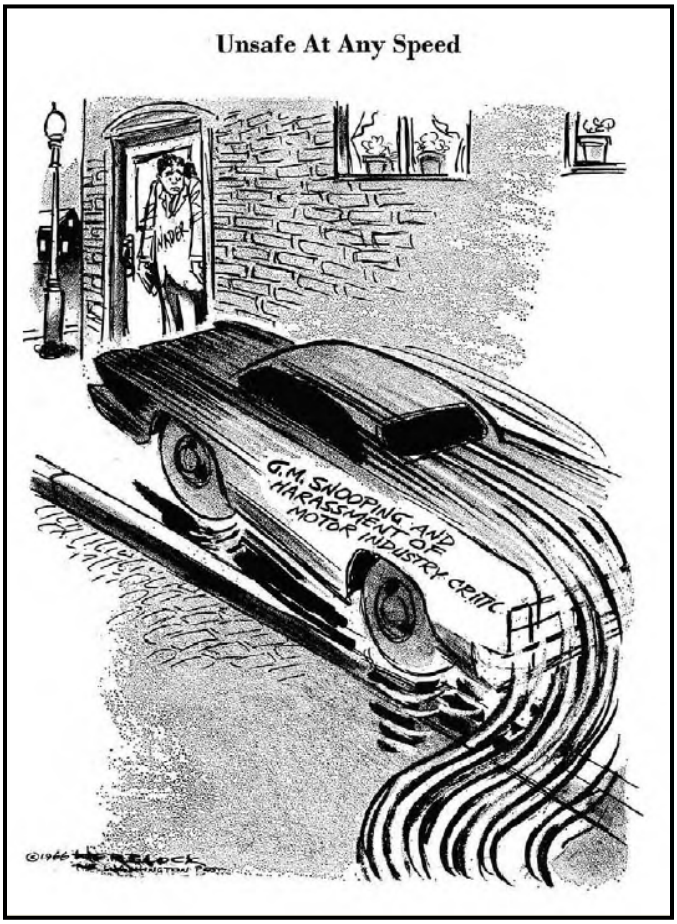
Source: Reading Eagle, Feb. 18th, 1962, p. 41

While the design-oriented framing gained credibility and visibility, the 3E-framing began to weaken before public opinion, because of increasing doubts about the effectiveness of education campaigns. In 1958, the industry journal *Automotive*

News pointed to a 'safety slogan fatigue', "brought on by an overdose of jingles, catchy phrases and righteous warnings asking us not to kill ourselves" (quoted in Weingroff and Seabron, 2003, p. 93). In the early 1960s, criticisms also appeared in magazines (e.g. *Consumer Reports* and *Nation*), arguing that education efforts diverted attention from the car to the driver (Eastman, 1984). The book *Safety last: an indictment of the auto industry* (O'Connell and Myers, 1966) accused the President's Committee for Traffic Safety (chaired by GM's CEO) of being "an example of the sloganizing approach at its apex" and a "public relations coup" that directed public attention away from vehicle design (p. 62).

A scandal around Nader's (1965) book, *Unsafe at any speed*, escalated public opinion around the issue. Nader synthesized the new body of crash injury research and described the industry's longstanding political opposition to vehicle safety standards. He "painted the nation's auto executives as callous, if not worse, in their attitude towards safety" (Luger, 2000, p. 69). When Nader was called to testify in the 1965-6 Ribicoff hearings, GM hired a private investigator to look into Nader's personal affairs, with the goal of blackmailing or discrediting him (Luger, 2000). But GM's strategy backfired when these investigations became public (Figure VI.10), making Nader into a national figure. GM was forced to publicly apologize, which "sent shock waves throughout the industry and further diminished the credibility of the automakers among the public" (Luger 2000, p. 70).

Figure VI.10: GM's harassment of Ralph Nader by Herblock



Source: Johnson and Katz (2009)

Regime outsiders. The crash-injury research sponsored by *Liberty-Mutual Insurance Company* resulted in the 'Survival Car I' (1956MY), a non-operational prototype mounted on a conventional 1955 Ford Four sedan that included sixty safety innovations, both incremental (safety belts, 'extra-heavy' padding, recessed buttons, wider brakes) and also 'unusual' ('centre driver's seat' and passenger seats facing backwards, levers instead of steering wheels, a front-view mirror that employed side-periscopes to 'look ahead'). In 1961, to demonstrate "the feasibility of safety improvements within conventional production-line automobiles" (Nader, 1965, p. 208), Cornell's engineers developed the 'Survival Car II'. This was an *operational* prototype, mounted on four 1960 Chevrolet four-door sedans, which included twenty-four safety features, such as capsule seats, collapsible steering columns, dual braking systems, and rollover bars (Eastman, 1984). This resulted in pressures both in the task environment *and* in the institutional environment: it influenced perceptions of consumers as the prototype received lots of publicity, drawing public and political attention to technological alternatives (Nader, 1965; Eastman, 1984).

Policy-makers. Political support for the 3E-framing weakened as investigative hearings culminated in more negative attitudes towards the car industry. The *Special Subcommittee on Traffic Safety* held several hearings (1956, 1959), which increasingly advocated an active role for the federal government through the establishment of car-safety standards (Bollier and Claybrook, 1986). As a first step, the House mandated safety devices for the governmental fleet in 1959 (Weingroff and Seabron, 2003). Responding to the pledge from the medical community, certain states subsequently introduced mandatory seatbelt *use* laws (Wisconsin 1961, New York 1962), which indirectly mandated seatbelt *installation* by automakers.

The 1965-6 Ribicoff hearings, which invited automakers' top executives to testify in Congress, accelerated the regulatory process. The hearings exposed "the industry's disregard for vehicle safety" (Luger, 2000, p. 8). Nader's testimony "provided a scathing description of the safety establishment and the automobile industry" (Weingroff and Seabron, 2003, p. 150). Senator Robert Kennedy criticized the lack of investment in safety, noting that "if [GM] had spent only [one] percent of its [1964] profits on safety, [investments] would amount to $17 million" (Luger, 2000, p. 68-9), instead of just US$1.25 million (both figures in nominal dollars). The *Washington Post* (July 14, 1965) commented that "Kennedy dealt with [GM's executives] much as if he were examining a couple of youthful applicants for a driver's license who hadn't done their homework" (quoted in Luger, 2000, p. 69). High public attention, scandals and poor performance of the executives during these hearings were the "turning point in creating a climate in Congress conducive to the passage of a meaningful automobile safety bill" (Eastman, 1984, p. 246): the 1966 *National Traffic and Motor Vehicle Safety Act* (NTMVSA).

VI.4.5.2. Car industry issue responses

Socio-cultural and political strategies. The industry collectively deployed political strategies to hinder safety regulations. In subcommittee hearings the Automobile Manufacturers Association (AMA) lobbied against regulations, highlighting the "lack of demand" for safety innovations (Weingroff and Seabron, 2003). In the

Ribicoff hearings, automakers opposed federal regulations and argued for a voluntary approach (Eastman, 1984). These hearings turned into a public relations disaster, because executives responded poorly to critical questions. The *Wall Street Journal* (July 20, 1965) commented that the industry "underestimated the opposition and failed to prepare adequately" and ascertained: "so dismal [was] the auto industry's performance at the Senate's safety hearings that the chances of Federal legislation in the field have markedly increased".

While GM acted alone in harassing Nader, the industry's collective legitimacy and reputation were undermined by the subsequent scandal. Moreover, congressional investigations found that from 1960 to 1966 the industry promoted 426 recall cases of faulty automobiles. These were *secret* recall campaigns, which made policy-makers perceive the industry not only as uncooperative, but also 'unreasonable' (Luger, 2000). In this context of weakened cultural and political legitimacy, the industry could not prevent the 1966 NTMVSA.

Technological innovation and positioning strategies. Early cracks appeared in the closed industry front as firms developed different orientations towards safety-related design innovations, ranging from public opposition (GM), through relative passivity (Chrysler), to positive engagement (Ford). To counter declining market shares, Ford decided to incorporate safety innovations in 1956MY cars with the strategic aim of gaining first-mover advantages (Eastman, 1984). Its 'safety package' included safe door latches; recessed hub, dished steering wheel with energy absorbing capability; padded instrument panels; and redesigned rear view mirror. Ford also offered (lap) seatbelts as optional equipment for c. $130 (2011 dollars). Ford's original safety advertising campaign (Figure VI.11.a) attracted positive attention (Bollier and Claybrook, 1986), and its strategy seemed to work. A survey at the *Chicago Auto Show* (1956) indicated that potential Ford buyers saw safety as a reason for their choice (Eastman, 1984).

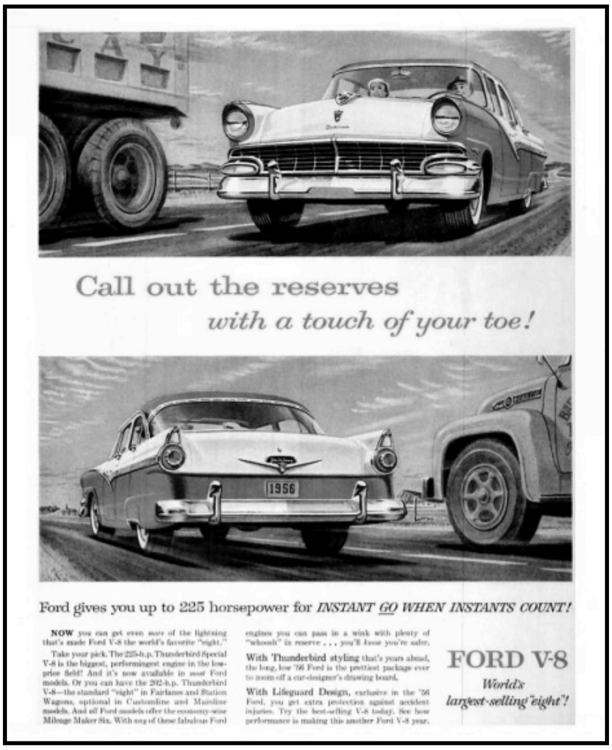
Yet, Ford's strategy attracted controversy amongst the rest of the auto industry, particularly GM:

> *The implication was clearly not only that the Ford was safe, but, by extension, that the rival Chevrolet* [GM's subsidiary] *was less safe. This suggestion was reinforced by the photographs that dealers were instructed to display in Ford showrooms, which claimed to show that passengers in a*

> *new Ford were more likely to survive a given accident than those who travelled by Chevrolet.* (Stevenson, 2008, p. 193)

GM "expressed its disapproval of the safety campaign directly to Ford's top executives", using "the weight of its enormous monopoly power to have it halted" (Luger, 2000, p. 63). Following GM's threat, Ford dropped its superior safety claims and returned to traditional advertising themes such as increased horsepower (Figure VI.11.b).

Figure VI.11 (a-b, left-right): The 1956MY safety-led ad campaign (by Ford) started with strong claims (left) but was weakened after negative reaction from rest of industry (right)



Source: Old Car Advertisements, available at: http://www.oldcarads.ca/Ford/1956/dirindex.html; downloaded on Dec. 6th, 2010

GM thus succeeded in apprehending Ford's safety initiative, and restored a closed industry front. "Ford terminated its safety campaign in the spring of 1956 after an internal policy struggle won by those who agreed with the General Motors analysis of the probable unsettling consequences of a vehicle safety campaign" (Nader, 1965, p. 96). Ford's initiative was labelled a market fiasco, hardening the belief that 'safety does not sell', which became an industry truism for the following three decades (Kurylko, 1996). Henceforth, the American car industry argued against mandated safety features with the economic argument that these were not demand by consumers.

After Ford's initiative, *technological strategies* continued to focus on accident-avoidance innovations[120]: improved headlights, emergency flashing systems (Eastman, 1984). One exception was the installation of front-seat lap-belt as standard equipment, following Studebaker's lead in 1963 (Bollier and Claybrook, 1986). Another exception was the exploration of a very radical technology: airbags, which had been patented by an independent inventor in 1953 (Strother *et al.*, 2003). The patent attracted some attention from Ford and GM, which experimented with inflatable restraints in the late 1950s (Sherman, 1995). But they discontinued airbag research activities when these encountered two engineering challenges: (a) quickly, reliably, and accurately sensing a collision; and (b) inflating the air bag in about forty milliseconds, which is faster than the blink of an eye (Sherman, 1995). The 21 airbag patents between 1953 and 1966 (Figure VI.2.d) were all assigned to independent inventors or auto industry outsiders.

VI.4.5.3. Influences of broader industry contexts on issue life-cycle

Local air pollution and car quality were two other issues that encroached upon the car industry, undermining its social and political legitimacy. Social movements, such as *Stamp Out Smog* (SOS), criticised automakers for not addressing HC, NO_x and CO emissions. These concerns spilled over to policy-makers, who introduced initial regulations in the 1960s. These acts signalled increasing willingness for legislative actions on social issues (see Chapter V).

Declining car quality, which resulted in embarrassing recall campaigns (Figure VI.12), was due to limited investments in factories and parts supply. To increase profits and stock value, automakers postponed process and product innovation, which were seen as unnecessary expenditures (Yates, 1983).

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[120] Yet, *development* of occupant-protection technologies happened in the period, as indicated in Figure VI.6.d.

Figure VI.12: Herblock's cartoon mocking American automakers' recall campaigns, which became commonplace events in the 1960s

Source: Johnson and Katz (2009)

VI.4.6. Implementing safety standards: Compliance, resistance and the seatbelt-airbag controversy (1966-1976)

This period presents many underlying processes that fit well with phase 4 from the DILC-model: (a) the safety issue spilled over to the task environment when the implementation of regulations and safety standards began; (b) the car industry complied with safety innovations and increasing R&D investments in more radical alternatives (airbags); (c) GM's initial support for airbags caused a crack in the industry front. But the industry also resisted the implementation of new standards (with litigation, lobbying, threats, and inconvenient technical designs), playing off seatbelts against airbags. When GM abandoned airbags in 1976, the industry front closed down again, shutting the window of opportunity for faster change. Spillovers to consumers remained limited and public attention to safety decreased following the 1973 oil shock and subsequent recession.

VI.4.6.1. Pressures around issue

Social movements and public opinion. After the 1966 NTMVSA, public attention declined (Figure VI.2.a) as the safety issue moved to the administrative arena and became more technical. But the medical profession, crash-engineers and special-interest organizations (such as Nader's *Centre for Auto Safety*) continued to exert pressure (Luger, 2000). The *Consumers Union* also exerted pressure by providing consumers with technical data and accident statistics and helping them find attorneys for litigating automakers for defective products (Mashaw and Harfst, 1990).

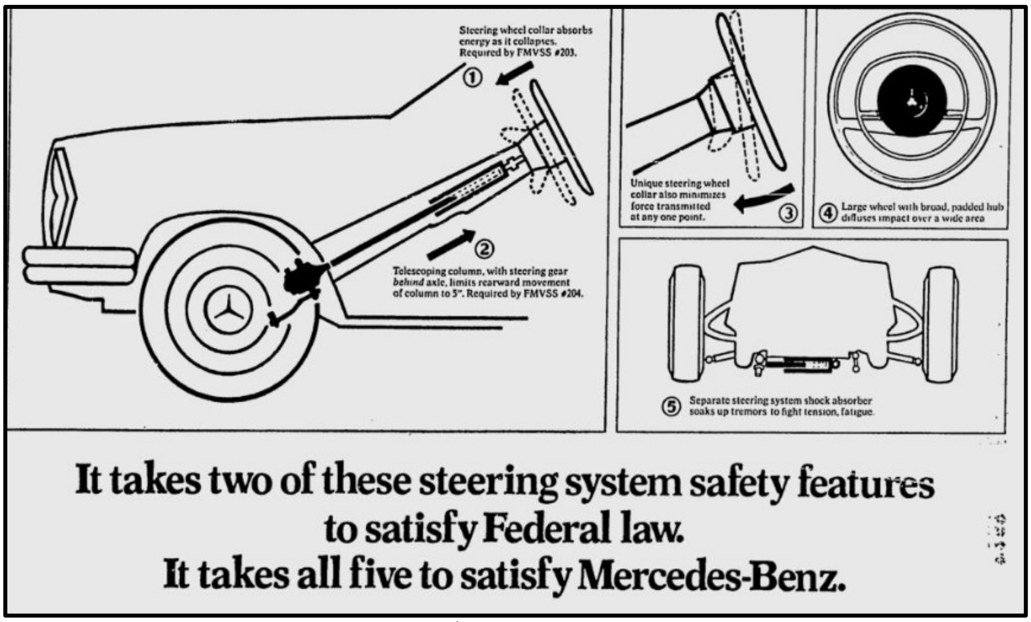
Policy-makers. The NTMVSA was a milestone because it asserted an active role for Federal government in auto-safety; articulated safety performance standards for motor vehicles; and established the NHTSA (National Highway Traffic Safety Agency) to implement the new regulations (Bollier and Claybrook, 1986). The new safety standards included crash avoidance (e.g. lights, brakes, headlamps, tires), crashworthiness (e.g. padded instruments, head restraints, seatbelts, energy absorbing steering columns) and post-crash (e.g. fuel systems integrity) specifications. Congress specified that the new standards be 'reasonable, practical and appropriate'. These vague specifications became the source of conflicts with the car industry (Luger, 2000), moving the struggle from the political to the implementation stage (which is reflected in attention indicators, cf. Figure VI.2).

Particularly Standard 208 (seat-belts) became the focus of a long-lasting controversy, when, in 1969, NHTSA upgraded the initial standard to an automatic crash protection (or passive restraint[121]) standard. There were two technical options to meet this standard: airbags or seatbelts with an ignition-interlock system (which sounded an alarm and prevented engine ignition unless the driver buckled up).[122] Regulators, safety advocates, consumer interest groups, and the insurance industry assumed that the standard meant the installation of airbag systems (Bollier and Claybrook, 1986; Miller, 1988). But automakers preferred the cheaper solution – seatbelts – because airbag technology was difficult and more expensive (Abeles, 2004). In 1970 regulators postponed the standard to 1973, acknowledging an 'inadequate supply' of airbags (Miller, 1988). Ongoing opposition from automakers resulted in further delays and modifications, so that by 1976 the passive restraint standard faced an impasse.

[121] In the United States, 'passive safety' is understood as comprising those technologies that do not require action from the driver/passenger.
[122] Later, Volkswagen developed the automatic seatbelt technology to comply with Standard 208 (Schnapp, 1979).

New entrants and regime outsiders. The *Insurance Institute for Highway Safety* (IIHS) also became involved in the airbag struggle, performing vehicle safety tests (as inputs for standards) and lobbying for auto-safety regulation (Nishida, 1996). And insurance companies such as Allstate ran advertising campaigns about the reliability of airbags. European manufacturers (e.g. Mercedes-Benz, Volvo) began using safety as an entry point into the American market. Their advertisements, which highlighted voluntary design changes that went beyond regulatory requirements (Figure VI.13), helped build consumer awareness.

Figure VI.13: Mercedes-Benz safety advertisement (1970)



Source: The Palm Beach Post, 1970, (Aug., 28th), C11

Mercedes also collaborated with Bayern-Chemicals (Nilsson *et al.*, 2003) to develop airbags, using the latter's capabilities in gas generator technology. Mercedes saw airbags as complement to, not substitute of, seatbelts. After GM changed its strategic position on airbags (see below), Mercedes became "the only car manufacturer seriously working on airbags" (Nilsson *et al.*, 2003, p. 52).

VI.4.6.2. Car industry issue responses

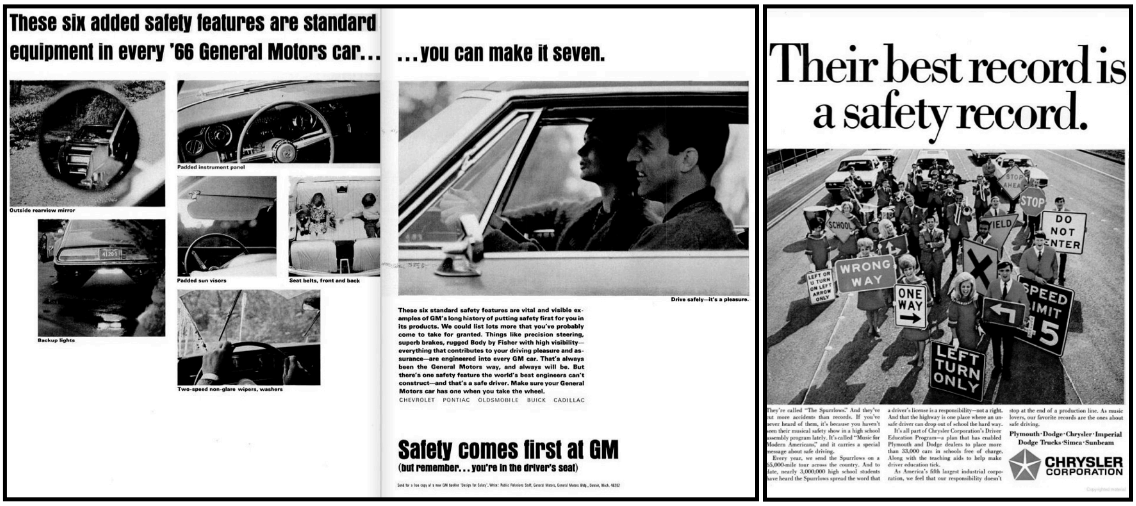
Socio-cultural and political strategies. Automakers used strategies to resist the 1966 NTMVSA, claiming that the new standards were technically unfeasible and publicly threatening to close down factories (Bollier and Claybrook, 1986). The industry also attacked the original Standard 208, claiming that Americans would not wear seatbelts (Luger, 2000). Automakers installed large, restrictive and cumbersome belts, with shoulder belts separated from lap harnesses. "If people wanted an excuse for not taking the trouble to buckle their seatbelts, the manufacturers gave it to them" (Waters *et al.*, 1998, p. 1338-9). The industry also opposed the upgraded Standard 208, suing NHTSA in the US Court of Appeals. The court endorsed NHTSA's authority to issue technology-forcing standards, but suspended Standard 208 because of a technical specification that should be corrected (Bollier and Claybrook, 1986).

The industry engaged in direct lobbying, drawing on economic arguments to call for regulatory easing: top executives met with President Nixon, warning that safety (and emission) regulations would increase car prices and damage Detroit's competitiveness (Doyle, 2000). The political strategies succeeded: the compliance deadline was extended and NHTSA allowed automakers to comply with seatbelt interlock systems. But ignition interlock systems annoyed users, who felt their freedom was curbed (Bollier and Claybrook, 1986). Many drivers disconnected the system and wrote complaint letters to policy-makers (Luger, 2000). In 1974, Congress repealed the requirement of the interlock system, forbade any buzzer-system, and ruled that any safety standard different than an active seatbelt mandate had to be voted by both Houses (Abeles, 2004). The passive restraint standard thus reached a stalemate.

Technological innovation and positioning strategies. Although the industry formed a closed political front, there was strategic manoeuvring with regard to technology and positioning strategies. The industry's strategy towards the task environment can be qualified as 'reluctant compliance', with political use of innovations, but positive positioning and exploration of alternatives. Automakers began offering certain safety innovations as standard equipment in advance of the announcement of standards (1967), e.g. energy-absorbing armrests, collapsible ('telescoping') steering columns, energy-absorbing bumpers, roll-over safety structures, and anti-skid breaking systems (an early anti-lock braking system by Chrysler) (Abernathy *et al.*, 1983; Luger, 2000). With these mostly incremental innovations, they also aimed to delay the speed of change (Bollier and Claybrook, 1986). When NHTSA announced stricter safety standards, automakers complained that their ongoing production plans were too advanced for major engineering changes and retooling to be implemented without great expense and difficulty (AP, 1967; UPI, 1967).

Yet, the industry also began advertising safety innovations. “Now that certain safety provisions were mandatory, and the issue was irreversibly on consumers’ agenda, it was worth stressing the competitiveness of one’s product.” (Stevenson, 2008, p. 198). GM’s 1966 advertising campaign (Figure VI.14.a), which claimed that “Safety comes first at GM (but remember… you’re in the driver’s seat)”, incorporated car design, but also continued to highlight driver responsibility. Chrysler (Figure VI.14.b) and Ford also used safety as an advertising theme (Stevenson, 2008). This marketing and positioning strategy can also be seen as a socio-cultural approach to regain legitimacy and confidence from consumers.

Figure VI.14 (a-b): GM’s and Chrysler’s ad campaigns from late 1960s focused on safety



Sources: Life, 1966, 60 (1), p. 9-10, and Stevenson (2008), respectively.

While automakers politically resisted mandatory safety standards and, in particular, airbags, they privately restarted R&D programs on this technology because military and space research had developed promising options for the engineering challenges related to collision sensing and rapid airbag inflation (Sherman, 1995; Struble, 1998; Strother *et al.*, 2003; Nilsson *et al.*, 2003): (1) the US army developed a new detonating valve for very rapid gas transfer, (2) *Thiokol Chemical Corporation* developed a solid propellant (sodium azide) for aerospace rockets and missiles, which could be used for airbag inflation; (3) research on time-delay ordnance fuses[123] resulted in a simple and reliable electromechanical collision sensor. Building on these inventions, carmakers restarted airbag research in the late 1960s, leading to a peak in airbag patenting activities in the mid-1970s (Figure VI.2.d).

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[123]Target-sensors to delay detonation of missiles.

Ford engaged in external collaborations (with automotive supplier *Eaton, Yale & Towne*), while GM pursued in-house R&D (Strother *et al.*, 2003; Sherman, 1995).[124] Ford decided not to market the new technology when field tests showed fatality risks with child-size dummies and when an airbag failed to deploy during a demonstration experiment in the presence of its CEO (Bollier and Claybrook, 1986).

Up to 1974, GM had invested about $300 million in its airbag project (Griswold and Henson, 2003), using expertise from its AC (Delco) Electronics aerospace division. In 1976, the industry's front on airbags seemed to crack when GM equipped 1,000 Chevrolets with the radical technology for field testing and announced plans to set up a sales program in 1974-1976 (Struble, 1998). GM tooled up to produce 100,000 airbag-equipped cars and envisaged sales of more than 300,000 (Abeles, 2004). Although GM subsidized the cost of airbags, consumers bought only 10,000 (Albaum, 2005). This failure caused GM to "shift [...] from a pro-bag position to an anti-bag position" (Lund, 1975, p. 32) and hardened the belief that consumers were not interested in safety.[125] By the mid-1970s, Detroit automakers therefore geared most of their R&D efforts towards automatic seatbelt systems (Schnapp, 1979), leading to decreasing airbag patents Figure VI.2.d).

VI.4.6.3. Influences of broader industry contexts on issue life-cycle

Societal pressures regarding safety aligned positively with three broader developments. First, they linked up with the general rise of an activist culture in the 1960s and anti-corporatist sentiments. Second, it resonated with the issue of air pollution, which gathered pace and led to frustrations about the car industry's reluctance to implement substantive solutions. The perceived disregard for public interests damaged the industry's legitimacy and strengthened the political willingness to introduce strict legislations (see Chapter V). Third, safety was linked to increasing concerns about the quality of American cars, as indicated by 900 recall campaigns between 1966 and 1972, which involved 25 million vehicles with defects (Luger, 2000).

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[124] Chrysler also started an airbag programme, which however "did not result in hardware being integrated into vehicles" (Struble, 1998, p. 55).

[125] Critics also proposed other explanations. Schnapp (1979, p. 50) claims that "GM did not aggressively market air bags to its customers". Additionally, airbags were only available in large-sized cars, which were not in demand after the 1973 oil shock (Albaum, 2005).

Although the industry reluctantly complied with (some) NTMVSA standards, it did not incorporate safety (or environmentalism) in its mission in the period[126], despite the safety innovations and advertisements. The shared *belief* was that both issues were externally imposed by regulators, not demanded by customers. Additionally, American automakers paid more attention to economic problems in the early 1970s, related to market contraction[127], the 1973 oil crisis, and increasing competition from German and Japanese carmakers (Halberstam, 1986). The industry therefore began developing a new framing strategy, emphasizing that regulations were costly, hampered the industry's financial situation and threatened the US economy (Luger, 2000).

VI.4.7. Moving backwards due to weakening political pressure (1976-1984)

The core dynamic is a new framing struggle in the political arena (about the proper 'passive safety' technology, and whether regulations were cost-effective), with incumbents forming a closed industry front. The struggle was reflected in increased public attention. These developments indicate a *return to phase 3* in the DILC-model. Financial problems led politicians to adopt a different official problem framing (based on economic considerations) and support the car industry by weakening safety regulations. The political controversy over standards slowed down industry innovation efforts.

VI.4.7.1. Pressures around issue

Social movements and public opinion. Public attention to auto-safety increased (Figure VI.2.a), galvanized by safety scandals (e.g. the Ford Pinto subcompact car issue with fuel tanks), and a return to the behavioural framing, this time represented by the 'drunken driver' metaphor. Regarding Ford's case, the trigger was an article in *Mother Jones* (1977), which claimed that 500 people had burned to death in Pinto crashes, because of a flawed fuel-tank design. It further accused Ford of knowing about the hazard, but deciding not to fix it because cost-benefit analysis showed the change was not economically efficient. The public was shocked that Ford placed a dollar value on human life (Luger, 2000). Although Ford denied the accusations, it recalled 1.5 million Pintos in 1978 (Davidson, 1983).

[126] Indeed, the period fits with a phase four, and these changes in mission and beliefs are expected in phase 5.

[127] American car sales shrank in 1970 (-11.6%) and 1974 (-20.80%).

The scandal damaged the public image of Ford and that of the whole industry: "For the public, the case came to stand for Detroit's disregard for vehicle safety" (Luger, 2000, p. 83).

A new organized social movement, with groups such as *Remove Intoxicated Drivers* (RID), founded in 1978 in New York, and *Mothers Against Drunk Driving* [originally, Driv*er*] (MADD), founded in 1980 in California, revived the behavioural framing of car-safety in their campaign against the specific issue of drunk driving. The campaign initially focused on punitive measures and education, but gradually widened to include pricing and alcohol availability, underage drinking, advertising and marketing (Waller, 2002). This new sub-issue did not impact on the car industry's identity, but helped galvanize public attention to safety.

Policy-makers. Political safety pressure weakened throughout this period (cf. Congressional and Regulatory attention levels in Figure VI.2), because of concerns about the industry's economic problems and because Reagan's administration (1981-1989) favoured regulatory rollback.[128]

Because Standard 208 faced an implementation stalemate, they moved back to the policy-making arena[129]. Three consecutive Secretaries of Transportation issued contradictory rulings on the passive restraint mandate: in 1976, Coleman proposed to withdraw the mandate if automakers would produce between 40,000 and 400,000 airbag equipped cars for a demonstration programme (Bollier and Claybrook, 1986); in 1977, Adams reissued Standard 208, arguing that a demonstration programme was not necessary; in 1981, Lewis delayed compliance and subsequently repealed the standard altogether as part of a broader regulatory rollback (Bollier and Claybrook, 1986). It was argued that costs would outweigh the benefits: implementation of an automatic restraint standard was thought to require $1.0 billion (nominal dollars) with uncertain safety benefits (Miller, 1988).

[128] One important initiative established in 1979, was NHTSA's *New Car Assessment Program* (NCAP), a consumer information initiative, which rates the safety performance of new cars. The Program was part of the *Motor Vehicle Information and Cost Savings Act of 1972*. In 1980, NHTSA published the results in a book for consumers, which was however discontinued by the Reagan administration in 1981 (Bollier and Claybrook, 1986). The program itself continued, but the results would again be made public on annual basis – in an easy-to-understand format for consumers – only in the mid-1990s (Hershman, 2001).

[129] Note that the specification of standards was delegated to the NHTSA, which has the discretion to modify performance levels or to require different technologies. Thus, policy-making took place at the executive level. In the case of air pollution (Chapter V), emission standards were established by law, and any change had to be approved by Congress. Hence the declining level of Congressional activity, in spite of safety becoming a 'hot' political issue.

But consumer advocacy groups and automobile insurance companies took the government to court (Waters *et al.*, 1998).

In 1982, the Court of Appeals overturned the rescission of Standard 208. Automakers then took the case to the Supreme Court, which in 1983 upheld the previous decision (Bollier and Claybrook, 1986). The new Secretary of Transportation (Dole) then announced a complete review of the Standard, which meant more delay (Abeles, 2004). The subsequent review in 1984 reissued Standard 208 and mandated passive restraint systems by 1989 (Bollier and Claybrook, 1986). But it also created a loophole, establishing that the passive restraint standard would be annulled if, by April 1989, states accounting for two-thirds of the United States' population passed mandatory seat-belt use laws (Miller, 1988).

New entrants and regime outsiders. Insurance companies and other airbag advocates (such as consumer groups) contested the claims of American automakers (see below), arguing that costs were less than half of what automakers claimed (Abeles, 2004). Airbag suppliers further claimed that they had solved many of the technical problems cited by automakers. Nevertheless, many suppliers (such as *Eaton, Yale & Towne*) stopped production in the mid-1970s, because a market did not materialize (Albaum, 2005). The insurance industry however continued to lobby for an airbag mandate (O'Neill, 2009), and deployed information campaigns in the media (Figure VI.15). It also offered consumers discounts of 30% for cars with airbags (Abeles, 2004).

Figure VI.15: Allstate's information campaign calling for an airbags

Source: The Rotarian (February 1980, p. 15).

Japanese companies lagged behind in airbag development. In the late 1970s, Nissan performed some R&D, but preferred passive belts to comply with Standard 208; Toyota and Honda had airbag development programmes, which did not produce satisfactory results (Schnapp, 1979). The main problem was limited space for airbag systems in small cars (Struble, 1998). In the late 1970s, Mercedes-Benz continued to work on airbags, collaborating with Bayern-Chemicals, Bosch (which supplied crash sensors), Morton-Thiokol (which supplied inflators), and Petri AG (which supplied steering wheels with airbag module) (Nilsson *et al.*, 2003). In 1981, Mercedes began offering driver-side airbags as an option on luxury cars in Europe (Scott, 1980).

VI.4.7.2. *Car industry issue responses*

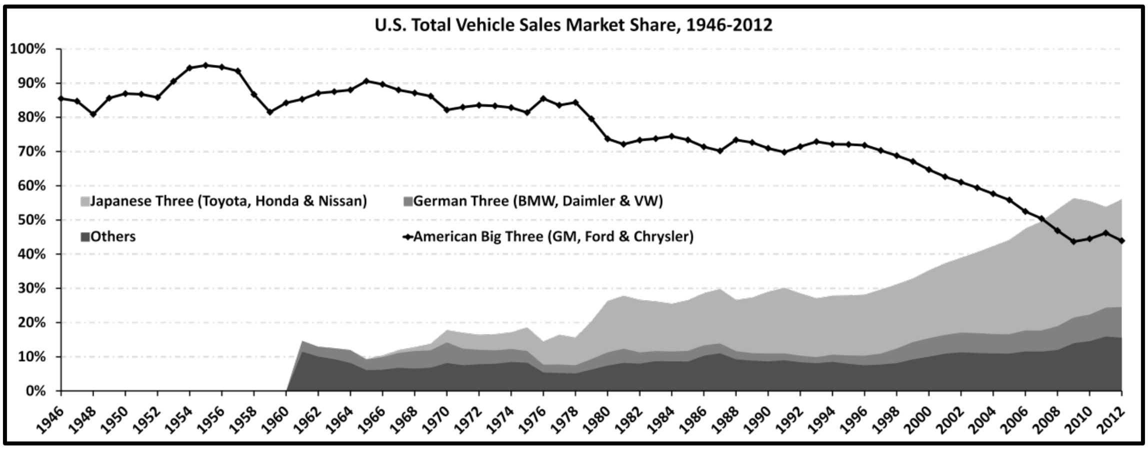
Political strategies. Automakers contributed to the regulatory weakening of safety standards, contesting or delaying their implementation with information strategies. They spoke at hearings, lobbied Congress, and expressed their concerns to the President (Albaum, 2005). They particularly contested airbags, alleging: (a) high costs and competitiveness problems (decline in sales, job losses) (MacLennan, 1988; Abeles, 2004); (b) limited effectiveness compared to seatbelts, (c) risk of liability claims in case airbags did not inflate properly; (d) lack of consumer demand; and (e) technical difficulties related to airbag installation in small vehicles and problems concerning out-of-position passengers and children in front seats (Struble, 1998; Kent, 2003). Automakers thus supported a cost-benefit analysis of mandated passive restraints.

Technological strategies. The legal struggles created regulatory uncertainty, which led automakers to diminish their safety innovation strategies, resulting in declining safety patents (Figure VI.2.d). The industry was also in dire straits, which diminished its interest in product innovations and led to an interest in organizational ('restructuration') and process innovations to compete with the Japanese (Ingrassia, 2010).

VI.4.7.3. Influences of broader industry contexts on issue life-cycle

The safety issue was negatively influenced by the industry's economic problems, which related to shrinking markets[130] and declining market shares (Figure VI.16), due to increasing Japanese competition. These problems caused substantial losses: Chrysler $10 billion (1978-1981), Ford $8 billion (1980-1982), GM $2 billion (1980) (Figure VI.17).

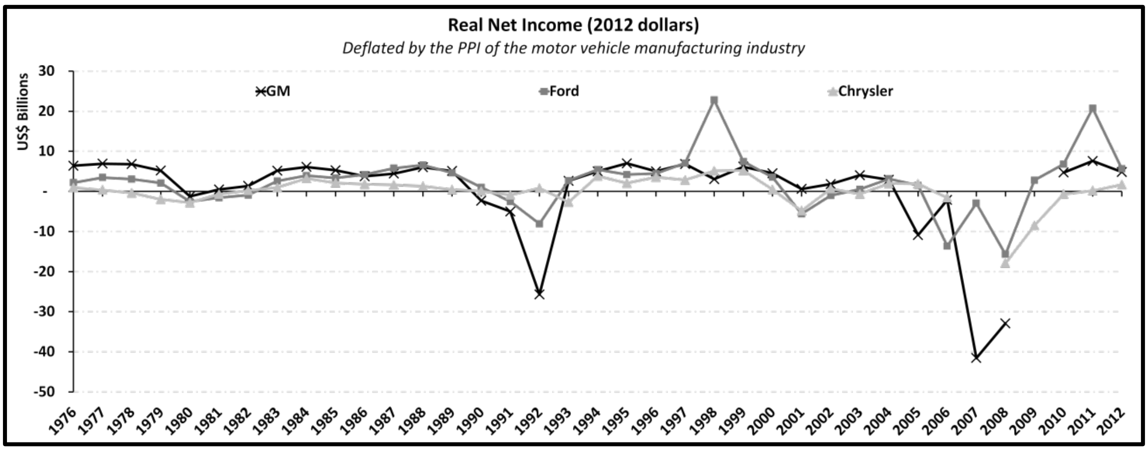
Figure VI.16: Share of American motor vehicle market by firm groups



Sources: Until 1960, White (1971); after, Ward's Automotive Group (2013)

[130] Overall car sales declined in 1979 (-8.23%), 1980 (-19.14%), 1981 (-5.82%) and 1982 (-2.23%).

Figure VI.17: Net income of the Big Three American automakers, 1976-2012



Sources: Freeland (2001) for GM; Hyde (2003) for Chrysler; and Studer-Noguez (2003) for Ford

The economic problems decreased the industry's attention to the safety issue and diminished the willingness to comply with safety regulations, leading to enhanced lobbying activities for regulatory relief. The industry continued to see safety as externally imposed and did not include it in its *mission*. Industry resistance to safety also had an ideological component, as a New York Times editorial (NYT, 1981, p. A30) noted: "The real mystery (...) is why the auto industry fights safety so hard. The explanation for the mystery may be as simple as it is sad: American auto makers (...) oppose airbags because they would give regulation a good name".

The economic problems also weakened political safety pressure, as policy-makers stepped in to protect the American car industry. In 1980, President Carter announced a plan to help the auto industry with tax reliefs, relaxation of federal regulations, and financial aid. This opened "a new era of cooperation between government and industry" (Luger, 2000, p. 106). The Reagan administration was even more sympathetic to the industry's complaints, and set up a 'Task Force for Regulatory Relief', which proposed to roll back more than 34 safety, emissions and fuel economy regulations (Luger, 2000). Reagan also ensured that all regulations should be assessed with cost-benefit analysis (MacLennan, 1988). This empowered industries because it imposed the burden of proof (that benefits outweigh costs) on (weakened) governmental agencies, and because it restricted debate to economic issues, away from the health protection and social principles based on which the original laws were enacted (Bollier and Claybrook, 1986).

VI.4.8. Acceleration due to spillover to consumer preferences (1984-1991)

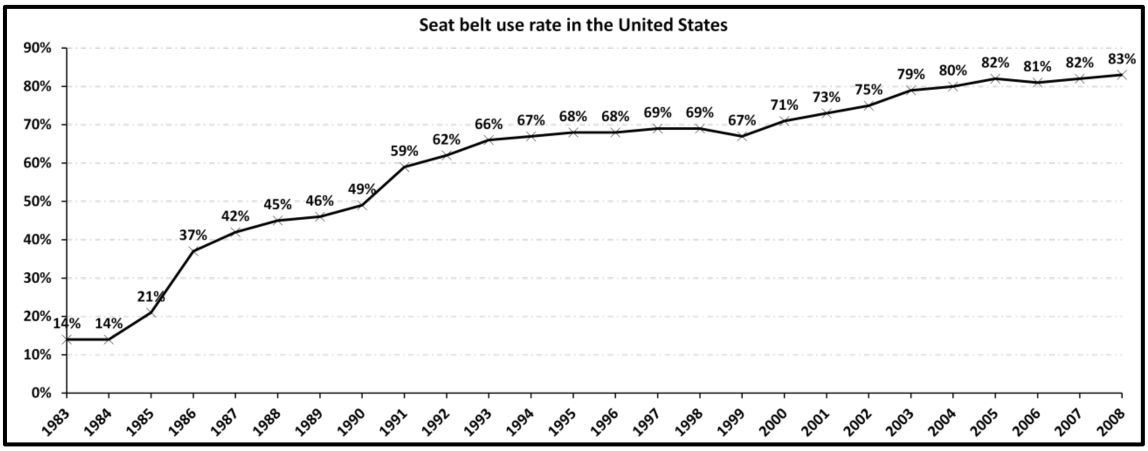
In this period, the auto-safety issue life-cycle seems to have moved forward again, presenting new dynamics that fit with the model's phase 4[131]: (a) frame conditions were changed with states introducing seatbelt use laws (but no new Federal regulation was introduced); and, more importantly, (b) safety concerns became part of consumer preferences, which created market demand for safety features. The period also fits phase 4, because significant cracks appear in the industry front. Firstly, the industry began to positively support seatbelts (in the hope of repealing airbags). Secondly, Mercedes introduced airbag-equipped cars in 1984, which sparked off an innovation race, with firms jockeying for position in the market that now demanded safety features.

VI.4.8.1. Pressures around issue

Social movements and public opinion. Auto-safety advocacy groups (e.g. *Public Citizen*) and the insurance industry created the *Advocates for Highway and Auto Safety* (1989) coalition that pressured NHTSA and Congress for improved safety standards and adoption of an airbag mandate (Brown, 1989; Mashaw and Harfst, 1990; Nishida, 1996). Public attention to automobile safety also increased in the second half of the 1980s (Figure VI.2.a), because of industry-sponsored seatbelt campaigns and the general rise of a health and safety movement (Centers for Disease Control and Prevention, 2011). Public debates about auto-safety began to influence behavioural and consumption practices, leading, for instance, to increasing use of manual seatbelts (Figure VI.18) even before most states had adopted mandatory use laws (MULs).

[131] Because in Geels and Penna (2013) this period ends in 1995, it has been assessed as a hybrid phase 4 and 5.

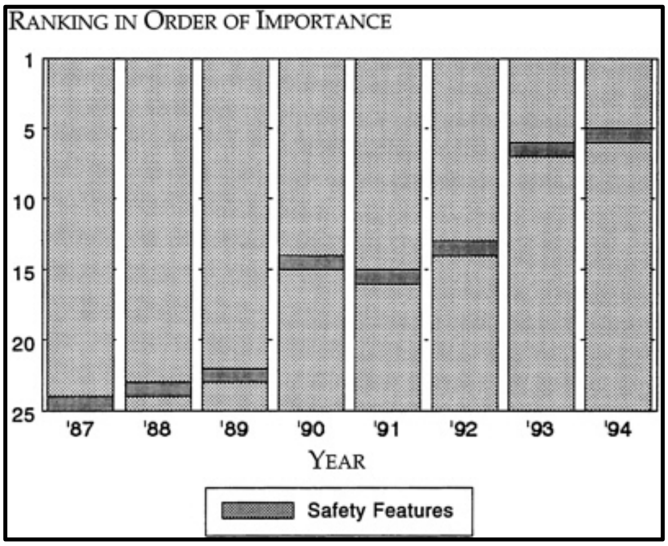
Figure VI.18: Increasing seatbelt use



Source: Based on data from Committee for the Safety Belt Technology Study, 2003, p. 6

Consumer demand. Safety began to spill over to consumer preferences, creating market demand for safety features such as airbags and anti-lock braking systems, initially in the upper market segment (Albaum, 2005). From the late-1980s, surveys also showed that consumers increasingly valued safety as a car purchase criterion (Abeles, 2004) (Figure VI.19)[132]. An article in the *New York Times* (January 26, 1990), titled 'Selling autos by selling safety' (Judge, 1990), signalled a 'cultural change', with technically sophisticated people demanding more car safety.

Figure VI.19: Relative importance of safety features as car-buying criterion



Source: National Research Council, 1996, p. 85

Changing consumer attitudes were related to several factors: (1) the 100-year long public debate about auto-safety and the more recent debate over passive restraint

[132] The Figure may not give a precise indication of the change, but Abeles (2004, p. 12) cites different surveys that show that by 1983, safety was the most highly valued attribute for c. 8-9% of consumers, while by 1987 that figures had increased to c. 12-13%. In the 1990s, one third of pollsters responded safety as the most important attribute when buying a car.

regulations; (2) the rise of health-and-safety movement; (3) demographic changes, such as the baby boomers reaching maturity and women becoming increasingly involved in new vehicle purchases (Automotive News, 1988); (4) the disclosure of auto-safety ratings (by consumer magazines and the insurance industry), and (5) car industry advertisements of seatbelts and other safety features.

Policy-makers. The conservative Reagan and Bush (Sr.) governments embraced an anti-regulatory and pro-business ideology (Luger, 2000). No substantive federal safety regulations were introduced in the 1984-1991 period. But the 1984 passive restraint ruling (208) from the previous period still held, including the loophole that automakers could avoid the airbag mandate by enhancing seatbelt use. Automakers subsequently lobbied states to pass Mandatory Use Laws (MUL) for seatbelts (O'Neill, 2009). In 1985, New York and several other states adopted MULs. But the hope of reaching the 2/3-population threshold was dashed in 1986, when Californian legislators (who wanted a state-level seatbelt MUL *and* a Federal mandate) specified that their MUL would apply if and only if was not counted by NHTSA (O'Neill, 2009).

With the loophole closed, policy-makers carried forward the phase-in schedule for passive restraint standard technologies (either airbags or automatic seatbelts): they should be installed in 10% of all new automobiles for 1987MY; 25% for 1988MY; 40% for 1989MY; and 100% for 1990MY (Abeles, 2004). Although many automakers were planning to comply with automatic seatbelts, the new schedule also provided an additional push for the unfolding airbag race.

Regime outsiders. While in the institutional environment the impasse was still being settled, in the task environment an airbag race began, triggered by Mercedes-Benz, which introduced optional airbags in 1984MY models for the American luxury segment (Albaum, 2005). Mercedes offered airbags as part of a 'Supplemental Restraint System' (SRS), which also included seatbelts (O'Neill, 2009). This changed the safety debate, because "[w]hat had been viewed by many people as a choice between belts and airbags was now becoming a recognition of the need for both" (O'Neill, 2009, p. 118). In 1985, the Mercedes airbags included digital sensors (developed by Bosch), which opened a new pathway for the development of 'smart' airbags systems (Nilsson *et al.*, 2003). Other companies responded to Mercedes, whose advertising (Figure VI.20) attracted positive attention (Abeles, 2004).

Figure VI.20: Mercedes-Benz 1984 advertisement of its airbag system

Source: New York Magazine, Apr. 23rd, 1984, 17 (17), pp. 82-3.

VI.4.8.2. *Car industry issue responses*

Socio-cultural and political strategies. Hoping to repeal Standard 208, the industry began promoting seatbelt use with advertising campaigns that called drivers to 'buckle-up'. Carmakers also founded a front organization, *Traffic Safety Now*, funded with $20 million (nominal) to organize a lobbying effort urging states to enact MULs (Reavis, 1985). The campaign was planned on a geographical basis, depending on the acceptance of seatbelts in each state. These industry actions to promote safety in the form of seatbelt use represented a significant shift in orientation (Bollier and Claybrook, 1986). It was the first time the industry would act together in *promoting* seatbelt use.

Technological strategy. While American automakers promoted seatbelts, they found themselves caught up in the airbag innovation race. In 1986, Ford announced that it would offer driver-side airbag as optional equipment (Crawford, 1985). To produce the device, Ford collaborated with suppliers such as Talley (inflator and module), Sheller (steering wheel), Breed (sensor) and Toshiba (diagnostic unit) (Nilsson *et al.*, 2003). In 1987, Chrysler 'upped the ante' and announced driver-side airbag systems as *standard* equipment in *all* big models (Abeles, 2004). GM offered optional driver-side airbags on 1988 and 1989 car-models, and provided rebates to consumers who purchased airbags *and* two other options (e.g. aluminium wheels, air conditioning). By the 1988MY, 1/3 of all new Big Three models had driver-side airbags as optional or standard equipment (my calculation based on information presented by Henry, 1988).

Airbag adoption was also stimulated by the insurance industry, which continued to offer discounts (20-30%) in insurance premiums for airbag-equipped vehicles (Henry, 1988; Abeles, 2004). With other foreign companies such as BMW, Saab, Volvo, Audi, and Porsche also offering airbags, the 'airbag race' accelerated, and airbag-related patenting activities surged (Figure VI.2.d). The shift towards airbags was related to perceived market demand rather than regulatory pressure (as automakers could also comply with Standard 208 with automatic seatbelts). A 1990 (Jan. 26th) article in the New York Times summarised the sea change in beliefs and strategies:

> *Lee A. Iacocca, now Chrysler's chairman and then president of Ford, said in 1972 that 'safety doesn't sell.' But the growing demand for safer cars* [...] *caused Mr. Iacocca to change his mind. Indeed, when Chrysler announced its commitment to air bags in 1988, the company ran ads with a picture of its well-known chairman, proclaiming, 'Who says you can't teach an old dog new tricks?'* (Judge, 1990, p. D1)

VI.4.8.3. Influences of broader industry contexts on issue life-cycle

The auto-safety issue benefitted from the broader health-and-safety movement, which got new impulse in the mid-1980s in response to concerns with occupational safety, industrial accidents such as Bhopal (1984) and Chernobyl (1986), and anti-smoking campaigns.[133] The development of airbags benefitted from the microelectronics revolution, which gathered pace in the 1980s. Airbags also co-evolved with the move towards 'total quality' control, as the need of full system reliability requires "quality assurance inspection and testing at a 100 percent level, as opposed to statistical sampling process" (Struble, 1998, p. 66). Another broader development was the creation in the mid-1980s of a new market segment around

[133] For a historical overview of the health-and-safety trend, see Centers for Disease Control and Prevention (2011).

the minivan (Ingrassia, 2010). This new design trajectory resulted in large cars and trucks, which created, however, new safety risks to bystanders and occupants of smaller vehicles.

VI.4.9. Spillovers to mainstream markets and strategic industry reorientation (1991-2000)

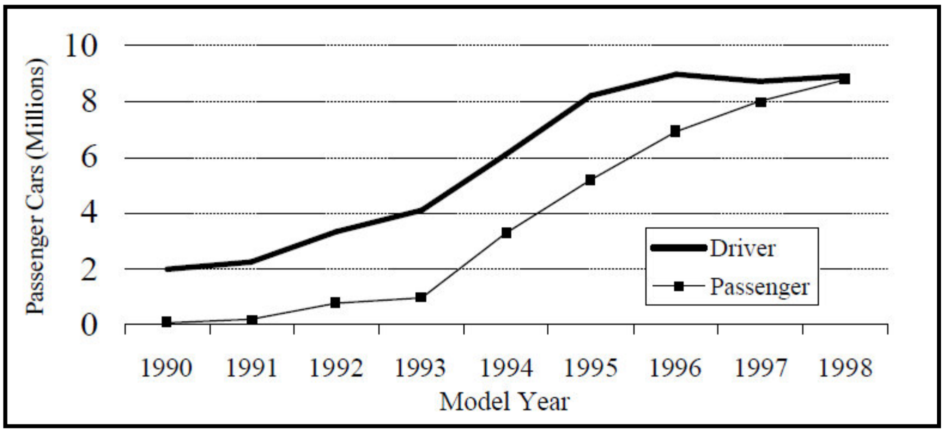
In this period, the auto-safety issue spilled over to mainstream markets, with demand for safety spreading to mainstream customers. This in turn stimulated the strategic reorientation of American automakers and the inclusion of safety in core beliefs and missions. The period can therefore be characterized as an ideal-typical phase 5.

VI.4.9.1. Pressures around issue

Social movements and public opinion. Mandatory seat-belt use laws, buckle-up campaigns, and safety feature advertisements caused a further increase in public attention to safety (Figure VI.2.a), culminating in the institutionalization of auto-safety as a cultural value and diffusion of behavioural practices such as seatbelt use (Figure VI.18). A sub-issue that generated debate and increased public attention (cf. Figure VI.3) was airbag-related fatalities of children in front seats (Albaum, 2005). The organization *Parents for Safer Airbags* called for NHTSA rulings on the placement of warning labels in cars (Pressler, 1998).

Consumer demand. Despite airbag-related children fatalities, many surveys showed that the public regarded airbags as a desirable technology (Graham *et al.*, 1997). This consumer preference translated into market demand, which stimulated rapid diffusion of airbags for drivers and passengers (Figure VI.21).

Figure VI.21: Number of airbags installed in passenger cars



Source: Abeles, 2004, p. 14

Policy-makers. The 1991 *Intermodal Surface Transportation Efficiency Act* mandated that by 1997 new cars should have dual airbags systems (i.e. in the driver-side *and* passenger-side). The Act however just officially endorsed an already institutionalized practice[134], because airbags were by then already a reality in the marketplace: the 20-year-long regulatory struggle on the passive restraint mandate thus came to a quiet end (Abeles, 2004). In response to the hazard to children issue, Congress carried out a hearing (Pressler, 1998), and the NHTSA issued mandatory warnings that parents should not place children in front seats (Albaum, 2005).

VI.4.9.2. Car industry issue responses

Socio-cultural strategy. In response to children-safety concerns, American automakers launched collective information campaigns (Figure VI.22), and promoted other individual efforts. "Virtually every automaker in the US [was] either planning or ha[d] started some sort of notification program to car owners addressing air bag safety. Several [were] going beyond the direct mail route, with other advertising and educational programs" (Halliday, 1996, online). In 1996, the Big Three announced the *Occupant Safety Research Partnership* to develop the 'next generation of airbags' (Pressler, 1998) and address the child-fatality problem, using new devices for deactivating and depowering inflated airbags at the discretion of owners (Albaum, 2005).

[134] It can be argued that the Act had some influence in the diffusion of passenger-side airbags.

Figure VI.22: Airbag safety campaigns by the Big Three (mid-1990s)

Source: Pressler (1998)

Positioning strategy. In response to new markets, the Big Three automakers fully embraced safety in their positioning and marketing strategies, which signalled major shifts in strategic attitudes, and an abandonment of the belief that 'safety does not sell'. Airbags, microelectronics and digital technologies also changed the industry's technical regime. Airbag-patenting activities exploded (Figure VI.2.d) as automakers exploited the new innovation potential, developing digital sensors, software algorithms, side and curtain airbags etc. (Struble, 1998). American automakers aimed to differentiate themselves from Japanese automakers, which lagged behind in the airbag race (Abeles, 2004).

VI.4.9.3. Influences of broader industry contexts on issue life-cycle

American automakers experienced major financial problems in the early 1990s, due to a recession (which depressed demand) and 'legacy' problems (post-retirement and health benefits) (Ingrassia, 2010): in 1991 losses amounted to $5.0 billion (2012 dollars) for GM, $2.5 for Ford, and $0.9 billion for Chrysler (Figure VI.17). In 1992, losses increased to $25.7 billion (2012 dollars) for GM and $8.1 billion for Ford, while in 1993, Chrysler faced a $2.7 billion loss. Unlike the late 1970s, these economic problems did not diminish the industry's attention to auto-safety, because it had become a commercial battleground, and safety was already part of the industry's mission and belief system. Financial fortunes of the Big Three improved during the 1990s, largely because of expanding sales of sport-utility vehicles in the large car and truck market.

VI.5. ANALYSIS

VI.5.1. Pattern-matching of DILC- model and case study

Despite the relatively good match between phases and periods (which I indicated in the introduction to each period), there were some minor deviations in the sense that certain empirical periods simultaneously included conceptual mechanisms from multiple theoretical phases. The 1946-1955 period, for instance, was primarily about framing struggles (phase 2), but also contained elements from phase 1 (new problem definition), 3 (defensive hedging by automakers; small firms deviating from the closed industry front), and 4 (involvement of macro-politicians). So, the case is in some instances more complex than the analytical model (as expected). Overall, however, empirical periods matched relatively well with conceptual phases in the DILC-model. This empirical complexity emphasizes the fact that the DILC-model is an ideal type, and, as such, should be used as heuristic tool.

In four ways, the case showed somewhat larger deviations from the ideal-typical DILC-model. These deviations suggest ways in which the model can be further elaborated. First, outside professional communities were more important than social movements in getting car design on the safety agenda. Activists such as Nader played a role in popularizing findings, but they drew on preceding research from medical doctors and crash-engineers. Scientific research should thus be made more prominent in the first or second phase of the DILC-model (problem-articulation).

Second, changes in the interpretation of auto-safety (in the 1950s and 1960s) influenced the *direction* of issue-evolution. This process is not yet explicitly included in the ideal-type five-phase model, but has important implications for the co-evolution of problems and solutions (see next section).

Third, competing issues (air pollution, car quality concerns, scandals about secret recall campaigns, Japanese competition, car styling, profitability problems) and changing macro-contexts (Great Depression, Second World War, rise of an activist culture, energy crises, economic recession, demographics, health and safety movement, micro-electronics revolution) can positively or negatively influence issue life-cycle dynamics. So, internal issue life-cycle dynamics are influenced by external developments, as the air pollution case has also shown. This is an important insight that has been overlooked by the Greening of Industry literature (see Chapter I).

The largest deviation is that the case did not follow a linear sequence of five phases, but moved back and forth between phases. This deviation however emphasises the internal validity of the DILC-model, because the multiple periods could be characterized as akin to certain theoretical stages. I therefore suggest that auto-safety was *interrupted* and later followed a *cyclical* life-cycle path (Bigelow *et al.*, 1993), with the issue moving backwards and forwards through the following phases: Phase 1 (1900-1924), Phase 2 (1924-1942), Interruption (1942-1946), Phase 2 (1946-1955), Phase 3 (1955-1966), Phase 4 (1966-1976), Phase 3 (1976-1984), Phase 4 (1984-1991), Phase 5 (1991-2000). I shall attempt at explaining this deviation from the model's 'normal' path in the next section.

VI.5.2. Explanation-building based on the DILC-model

VI.5.2.1. Explanation of mechanisms and factors leading to spills over to consumer preferences

As the case study has shown, the car safety issue life-cycle led to incumbent industry reorientation through a 'changes in consumer preferences' route. Although the 1966 NTMVSA forced technologies into the market, it did not succeed in triggering changes in the industry belief and mission. In fact, the issue returned to a political process due to implementation struggles, and reorientation only happened when the issue decisively spilled over to mass markets.

Which factors and mechanisms explain changing consumer attitude in the 1980s? As mentioned in the case study, new consumer attitudes were related to: (1) public and political debates about auto-safety and over passive restraint regulations; (2) the institutionalization of the health-and-safety movement; (3) demographic changes; (4) consumer education about relative car safety; and (5) car industry (regime actors' and outsiders') advertisements of seatbelts and other safety features. The key mechanisms unifying this process seems to be (a) 'attention advocacy' by activists and social movements and political struggles in the institutional environment and (b) outsiders' strategies in the task environment. While these mechanisms *were* present in the air pollution case, they were active for a couple of decades. So, time (not only timing) and duration of mechanisms also seem important in explaining changes in consumer preferences.

VI.5.2.2. Co-evolution of problems and solutions

With regard to specific dynamics in the co-evolution of problems and solutions, the case study showed that struggles over the meaning and problem definition of auto-safety were an important part of the process. (While these dynamics were mainly captured in the narrative approach, it is important to highlight that attention indicators – namely, patents by type (Figure VI.2) and media usage of issue-related terms (Figure VI.3) – also appeared to highlight how technical solutions co-evolve with how the problem is framed.)

The gradual and contested replacement of the 'education-enforcement-engineering' framing by the 'injury prevention' framing also had major implications for the solutions that were pursued. The car industry initially supported the 3E-framing, because it minimized their responsibility to develop solutions (by keeping car design off the problem agenda). When automakers were forced (in the 1950s and 1960s) to acknowledge the injury prevention framing, they reluctantly introduced safety-related solutions. Industry resistance lasted until the late 1980s when spillovers to consumer preferences created demand for safety innovations. Only then did automakers strategically reorient and include safety in their beliefs, mission, and innovation strategies.

So, the case study showed not only the general co-evolution of problems and solutions, but also that incumbent industry actors can become part of the solution when they see economic opportunities (as predicted in phase 5 of the DILC-model).

VI.5.2.3. Explanation of factors and mechanisms influencing the issue life-cycle path

The deviations from the 'normal' path can be explained with the other three deviations mentioned in the pattern-matching exercise and the mechanisms specified in the DILC-model:

- The interruption (1942-1946) was due to an external issue at the macro-context (Second World War).
- The issue return to phase 2 (1946-1955), where it was before the War, due to outside professionals contesting the established 3E-framing, causing reinterpretation of the problem and a framing struggle with the industry.
- The move to phase 3 (1955-1966) was related to simultaneous increases in public and political attention (due to the Ribicoff hearings, and outrage about Nader's harassment, and secret recall campaigns).
- The 1966 NTMVSA adopted an official – technical – framing and moved the issue to phase 4 (1966-1976). However, the backwards move to phase 3 (1976-1984) was related to an economic recession, financial industry problems, and changing political orientation (from public interest legislation to industry support and regulatory rollback).

I therefore suggest that four factors help explain the more complicated cyclical path: (1) changes in interpretations and framing; (2) changes in the orientation and relative strength of issue-proponents and issue-opponents; (3) alignment with or competition from other issues; and (4) changes in macro-contexts.

VI.6. CONCLUDING REMARKS

VI.6.1. Evaluation of the mixed-methods approach

The case study applied two quantification approaches: the exploratory visual examination and the meta-analysis of correlations. While the first method was again a useful first approach to the case, helping to establish initial patterns and relationships and to define sub-periods, the meta-analysis of correlations was somehow problematic (although it did reveal some intriguing relationships confirmed and explained by the qualitative narrative).

I believe the issue with the correlation analysis was due to methodological problems with data collection: firstly, given the length of the case study, the class-based search using the USPTO system could not be combined with a keyword search or with additional criteria such as 'filing date' or 'priority date' or 'assignee name'. While the class-based search can be regarded as a census, I had to compromise and use a sample of patents from a keyword search in the Google Patents system. The method therefore faced restrictions and will only be fully put to test in the contemporary case study (on climate change, Chapter VII), which will use a different data collection strategy. Secondly, by working with yearly observations, the statistical tests were compromised, because many sub-periods were rather short (although the statistical tests I used take sample size into account). Because the method did not result in many significant correlations, I was not able to experiment the method fully: the meta-analysis – comparison between correlation coefficients – was not adopted. In the next case study, I will attempt to overcome these limitations with an alternative analytical strategy (q.v.).[135]

Notwithstanding, the correlation analysis did reveal interesting 'within period' relationships that were confirmed in the narrative analysis:

a) An early connection between public and political attention with the objective side of the issue – this seem to be due to sense-making attempts and initial political sensitivity to the issue;
b) Further down in the issue life-cycle, a disconnection between attention indicators and the objective side of the issue – attention indicators are more connected to visible societal struggles;
c) Technology development in response to the issue is firstly attempted by regime outsiders and later by regime actors. The relative inertia of incumbents is explained by their adherence to the industry regime (lock-in and path dependence).
d) The dialectical process between incumbents and outsiders is accelerated by substantive regulation, and ultimately leads to an innovation race. However, the existence of consumer demand is a crucial factor in triggering the race.

A fifth quantitative insight has not been explored in the correlation analysis: the co-evolution of problem framings and technical solutions seems to have been captured by attention indicators (media usage of issue-related terms and patenting by types). The analysis of these indicators with quantitative methods could be the focus of further research.

In sum, despite the caveats of the meta-analysis of correlations, the combined use of the quantitative approaches with the narrative method proved very fruitful in the case study.

[135] Another solution would be to work with a dataset with monthly or quarterly. However, this is too time-consuming without machine-assistance, i.e. coding of an automatic search algorithm, a competence I do not possess.

VI.6.2. Implications for thesis' research focus and questions

Most empirical periods had a good fit with the conceptual phases, as noted in pattern-matching analysis. Deviations were explained with recourse to model specifications, corroborating the DILC-model's internal validity. In particular, the case brought about two important lessons for this thesis research focus:

1. The American society faced a 'Grand Societal Challenge'[136] with regard to safety and car fatalities. The case clearly showed that this challenge did not simply exist 'out there', but had to be articulated, defined, discussed and placed on policy agendas. The term 'challenge' itself seems to imply a general agreement about the societal problem, that all that is needed is the development and implementation of solutions. The car safety case study showed that these are however not given: the development of technical solutions depends on how the issue is framed. In this case, a behavioural framing that blamed drivers was connected to the development of solutions that helped drivers to avoid crashes, while a framing that blamed car designs for injuries and deaths led to the development of solutions that protect car-occupants in case of crashes. In the end, of course, both types of technologies contribute to address the issue. But a match between framing and solutions is needed depending on society's objective in addressing 'Grand Challenges'. And, here, the case showed that science (in the case, crashworthy engineering/crash research) plays important role in finding an appropriate match.
2. As the air pollution case study, this one further confirmed an important mechanism advanced by the DILC-model: the closing and opening of industry fronts. In the first two periods incumbent automakers created a closed industry front through organizations such as the *Safety First Committee* and the *Automobile Safety Foundation*, which embraced the 3E-framing and maintained the *status quo* through symbolic strategies towards the institutional environment. In subsequent periods incumbents succeeded in keeping this front closed and suppressing safety-related solutions: (a) relative outsiders (tyre

[136] While some could contest the claim that auto safety is a Grand Challenge, I believe it is so based on (a) the statistics shown in the first paragraphs of this chapters; (b) the duration of the issue life-cycle; and (c) the fact it *still* is a persistent problem for many developed and developing countries. Moreover, as argued in Chapter IV, the issue present characteristics akin to those spelled out by Soete and Arundel (1993) regarding new missions (aimed at tackling societal challenges).

suppliers in the 1930s, small new entrants in the late-1940s) were marginalized; (b) Ford's safety initiative in the mid-1950s was apprehended by GM; and (c) in the early 1970s, GM tried to break the front with airbags, but abandoned this strategy in 1976. The industry front finally cracked in the mid-1980s when an outsider (Mercedes-Benz) introduced airbags in a more safety-conscious consumer context. The ensuing innovation race signalled a breakdown of industry resistance and a reorientation of strategies, beliefs, and capabilities.

The finding highlights the general importance of tensions between closed industry fronts and escape attempts (to gain competitive advantage) and how these affected innovation strategies. It therefore throws more light on this thesis' research question(s), suggesting that major reorientation is unlikely until cracks appear in the industry front. The case study validates the key dialectical dynamics of the DILC-model.

VII. THE CLIMATE CHANGE ISSUE IN THE UNITED STATES AND THE RESPONSES FROM THE CAR INDUSTRY

VII.1. INTRODUCTION

Climate change is one of the 'Grand Challenges' faced by society, requiring low-carbon innovations in many sectors and industries to achieve significant cuts in emissions (European Commission, 2012). The transportation sector is one of the major contributors to carbon emissions. The sector is largely dependent on road transport, which dominates the moving of both goods and passengers. In 2005, road transport was the main source of CO_2 emissions in the US, Germany and the UK, and the second main source in Japan (OECD, 2004). While truck freight was responsible for 15% of the world's CO_2 emissions in 2000, light-duty vehicles contributed with almost 50% of these (WBSD, 2004). Considering that changes in personal mobility habits are not only slow, but indeed socially and politically difficult (Geels *et al.*, 2012; Wells and Nieuwenhuis, 2012), changes in light-duty vehicle technologies are crucial for a transition to low-carbon transport.

The recent trend in modal split of passenger transport in the US and the EU has been markedly steady since at least the 1990s (OECD, 2004). A change in this pattern does not seem likely in the foreseeable future, in view of the cultural embeddedness of cars in the society (Flink, 1990) and the economic dependence of individuals and states on the car industry for employment and revenues (Luger, 2000). In this context, the automotive industry's technology strategies in response to the issue of climate change become fundamental for the transition process.

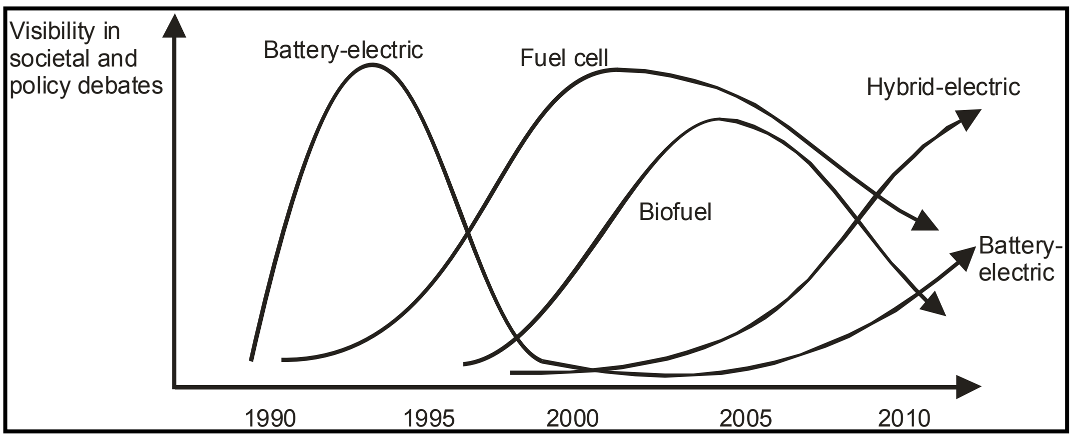
This case study[137] investigates low-carbon innovation and reorientation in the car industry in response to climate change pressures, with a focus on the United States. This case study plays a different role than the historical cases investigated in this thesis. It aims at three objectives: (a) it will investigate an issue life-cycle in which multiple competing technological solutions co-exist; (b) it will test the usefulness of the DILC-model in studying a contemporary case of 'Grand Societal Challenge'; and (c) it will do both with the aid of mixed-methods that

[137] The study appears in Penna and Geels (2013), which have been submitted to *Research Policy* for publication (currently going under first round of reviews). Yet, the case study I present here (1) have slight changes in the dates of the sub-periods; due to (b) refinement in the quantification method, which include the correlation analysis. Moreover, it draws on more pieces of evidence.

include sophisticated quantification approaches. The case study therefore aims at making theoretical, empirical and methodological contributions: it will elaborate the model in regards to 'technology hype-cycles'; test the model's analytical power beyond historical cases; and verify the suitability of the sophisticated quantitative methods in combination with the narrative approach.

Goals (a) and (b) are somewhat intertwined. The innovation studies literature contains many papers on various low-carbon automotive innovations, e.g. hydrogen and fuel cell vehicles (Bakker, 2010; Van den Hoed, 2005; 2007; Budde *et al.*, 2012), hybrid electric vehicles (Dijk and Yarime, 2010), battery-electric vehicles (Johnson, 1999; Dijk *et al.*, 2013), and biofuels (Duffield *et al.*, 2008). The focus on *single* innovations fails to acknowledge that firms (particularly in the car industry) face multiple possible low-carbon technologies, and that this diversity creates strategic uncertainty. It also pays insufficient attention to the possibility that low-carbon technologies may compete for public and political attention, for funding, and for market share. An implication of these complexities is that studies of single low-carbon innovations may be too optimistic in their future assessment. By investigating the implications of technology hype-cycles (Figure VII.1) to the climate change life-cycle, in the conclusion to this Chapter, I will therefore attempt to provide a more nuanced assessment of a likely scenario for the years to come, based on the DILC-model conceptualization.

Figure VII.1: An analytical interpretation of hype-disappointment cycles for green propulsion technologies in the past 20 years



Source: Geels (2012b, p. 477)

VII.2. DATA SOURCES & DATA COLLECTION PROCEDURES

Like the other ones, this case study draws on primary sources for quantitative indicators, while the qualitative case study is a triangulation of primary and secondary sources.

VII.2.1. Sources for quantitative indicators and data collection procedures

This case study offers the possibility of applying the three quantification methods, because a range of quantitative data is available from databases that allow for 'qualitative' refinements. I will therefore apply, firstly, the exploratory visual examination of attention indicator, which will be triangulated with a QLR test for structural breaks. I then will carry out the meta-analysis of correlations to generate first insights about patterns and relationships. These, together with qualitative knowledge of events, will be used to establish the sub-periods, which will provide the temporal bracketing for the narrative approach that will further investigate the insights.

In this case study, I will use the following attention indicators:[138]

- For *public attention*, I use the number of newspaper articles on climate change as proxy (Newig, 2004). I searched the *Nexis* database for newspaper articles (New York Times, USA Today, Wall Street Journal and Washington Post) with the keywords 'climate change', 'global warming' or 'greenhouse effect' (and derivations) in their <u>headlines</u>. The *Nexis* database allows for splitting the initial sample into articles with no/little/substantive references to the automotive industry,[139] thus adding a more nuanced, qualitative dimension.
- For policy-making activities *(Congressional attention)* and policy-implementation activities (*executive/regulatory attention*), I use climate-change related entries in the *Congressional Record* and the *Federal Register*, respectively. I searched these publications in the *HeinOnline* database with the same keyword string as above. While these proxy indicators present qualitative limitations, I also tried to add a qualitative factor by further searching for

[138] As in the historical studies, I also look at primary quantitative data other than attention indicators, collected from governmental sources (e.g. DOT, DOE, EPA, NHTSA) and industry journals and databases (e.g. *Ward's*; *Automotive News*).
[139] To split the sample, I used the tool that restricts results to articles with little/substantive mentions to a given sector.

entries mentioning 'fuel economy' or 'fuel efficiency', concepts historically related to (automobile) energy security regulation, but also key in controlling automobile greenhouse gas (GHG) emissions. This enabled to split each political and regulatory sample into three groups of documents: those citing only climate change (and synonyms), those co-citing the issue and fuel economy/efficiency, and those citing only fuel economy/efficiency. Furthermore, I also looked for articles mentioning 'climate change' (and other expressions used) and 'flex-fuel' or 'biofuel', whose use has also been regarded as a way to address carbon emissions[140]. The results allowed for a more nuanced analysis of how the issue of climate change, automobile fuel economy regulation and biofuels were jointly discussed or not.

- I use article count in the *Automotive News* (American edition) as proxy for how much attention the American auto industry dedicated to climate change (same search string as above) and different drivetrain technologies. Ups and downs in industry attention to technologies can be used to identify 'technology hypes' (Bakker, 2010). I distinguished between four *alternative-fuel vehicle* (AFV) *technologies: (1) fuel cell* and hydrogen vehicles (FCV); (2) *battery-electric vehicles* (BEV); (3) *hybrid-electric vehicles* (HEV) and *plug-in hybrid vehicles* (PHEV); and (4) biofuel, ethanol, and *flex-fuel vehicles* (FFV), and searched for articles with keyword-strings related to each of them.[141]
- As a proxy for technical development by the auto industry, I searched the USPTO database with the *AcclaimIP*[142] patent search and analysis application. I searched for patents related to the four alternative vehicle technologies, and, additionally, for those related to more fuel-efficient *advanced internal combustion engine* (aICE) technologies (e.g. improved fuel-injection systems, turbo charging, advanced valve management). My search methodology builds on Oltra *et al.* (2008) for the identification of 'eco-patents' on environmental technologies and 'green' products, which combines in the search string keywords and patent classes related to the focal-technology (see an example of

[140] This series may overlap with the other two citing climate change, i.e. articles citing climate changed (and fuel economy) may also be citing flex-fuel or biofuel.
[141] Articles citing more than one technology were assigned to all cited technologies.
[142] Previously known as 'CobaltIP'; available at https://www.acclaimip.com/ (accessed multiple times between August 1st, 2012 and April 12th, 2013).

search string for HEV-related patents assigned to General Motors in Table VII.1). This method allows for a reduction in 'noise' (i.e. exclusion of irrelevant patents, inclusion of relevant ones). I restricted the search to a selected set of twelve leading OEMs (BMW, Chrysler, Daimler-Benz, Ford, General Motors, Honda, Hyundai-Kia, Mitsubishi Motors, Peugeot-Citröen, Renault-Nissan, Toyota, and Volkswagen). Duplicated patents were excluded. Some patents appeared in the results of more than one technology, but I only included it in one technology category, according to the following order of precedence (from more radical to more incremental technologies): FCV > BEV > HEV > FFV/biofuel > aICE.

Table VII.1: *Example of patent search string (HEV-related patents in the USPTO assigned to GM)*

Technology	*CobaltIP* search string	Keywords	Classes	Assignees
Hybrid-Electric Vehicles	((PSCLS:180/65.21 OR PSCLS:903) OR (TTL:(("hybrid vehicle" OR "hybrid electric vehicle" OR "hybrid propulsion" OR "hybrid powertrain" OR "hybrid powerplant") NOT "fuel cell")) OR (ABST:(("hybrid vehicle" OR "hybrid electric vehicle" OR "hybrid propulsion" OR "hybrid powertrain" OR "hybrid powerplant") NOT "fuel cell")) OR (ACLM:(("hybrid vehicle" OR "hybrid electric vehicle" OR "hybrid propulsion" OR "hybrid powertrain" OR "hybrid powerplant") NOT "fuel cell"))) AND AN:("general motors" OR "Delphi Technologies" OR "delphi technology" OR "gm global" OR "gen motors" OR "delco electronics" OR "Saturn Corporation")	"hybrid vehicle", "hybrid electric vehicle", "hybrid propulsion", "hybrid powertrain", "hybrid powerplant"	180/65.21 (and subclasses), 903 (and subclasses)	"general motors", "Delphi Technologies", "delphi technology", "gm global", "gen motors", "delco electronics", "Saturn Corporation"
Comment	I searched for keywords in the patent's title (TTL), abstract (ABST) and claims (ACLM). The "AN" code searches the patent assignee field for certain keywords. The field code 'PSCLS' searches for patents with the predefined *primary* parent class(es) or any subclasses under the specified parent (primary) class.	I excluded patents citing "fuel cell". The assignee restriction increases the confidence that the patents are related to car technologies.	The 65.21 subclass is for "hybrid vehicles" under the class 180 ("motor vehicles"). The class 903 is a specific class for HEV-related technologies.	I included names of General Motors and its controlled subsidiaries that are known to file most of the OEM's patents.

Source: Author's construction.

The resulting set was ordered according to the patent's priority date, which is the date of the first filing of a similar claim in *any* patent office in the world, in order to better reflect the timing of the invention. To address the lag between filing and issuing a patent (which leads to a decline in the number of patents in more recent years[143]), I divided the number of patents of interest per year by the total number of patents per year by the selected carmakers to arrive at a percentage value.

- To capture consumer demand, I collected sales data for the different categories of AFVs, calculated the market share (relative sales) of the different green technologies in the US market, and plotted them over time. The data was collected from several sources: US DOE's *Alternative Fuel Data Center*[144], the *Electric Drive Transportation Association*[145]; *HybridCars.com*[146]; and the *US Energy Information Administration*[147]. Market-shares were calculated based on data from *Ward's Automotive Group* (2013). A complication with these figures concerns flex-fuel vehicles, which can be fuelled either with ethanol or gasoline or both, and thus may overestimate the share of 'alternative' fuel vehicles. Nevertheless, the data brings insight into the actual diffusion of different low-carbon vehicle technologies.

The quantitative analysis consisted of four steps: (a) firstly, I performed a visual inspection of the plots; then (b) I carried out a Quandt Likelihood Ratio test for unknown structural breaks[148] (Stock and Watson, 2006), in order to identify significant breaks in the time-series; thirdly, (c) I triangulated these findings with the visual examination of the plotted time-series and my *a priori* knowledge of key events in the case study to establish sub-periods; and finally, (d) I performed a meta-correlation analysis[149] to gain further insights into strength of association between the proxy-variables in each sub-period.

For this quantification approach, I used the following time-series: (1) the general series of public attention to climate change[150] (all three methods); (2) the

[143] For the same reason, I did not include 2011 and 2012 in my analysis.
[144] Available at www.afdc.energy.gov/afdc/data/; last accessed on April 14th, 2013.
[145] Available at http://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952; last accessed on April 14th, 2013.
[146] Available at http://hybridcars.com/market-dashboard.html; last accessed on April 14th, 2013.
[147] Available at http://www.eia.gov/renewable/afv/supply.cfm; last accessed on April 14th, 2013.
[148] The tests included one lag (two restrictions) to account for autocorrelations, and were applied to the natural logarithm of the variables. Following the methodology suggested in Stock and Watson (2006), the series were trimmed by 15%, meaning that the beginning and the end of each series were not included in the analysis, because the QLR statistic is dependant on these values.
[149] All statistics' procedures were performed with Stata 12, except for the difference between coefficients tests, which I performed online at http://www.quantpsy.org/corrtest/corrtest.htm (Accessed on April 19th, 2013).
[150] Note that the two series 'public attention to climate change' and 'public attention to climate change (with substantive mentions to the automotive industry)' are strongly (Spearman's rho of 0.9346) and significantly (1%) correlated to each other.

aggregated series of congressional attention to climate change (i.e. all Congressional record results citing climate change) (all three methods); (3) idem regarding executive attention (all three methods); (4) Automotive News attention to climate change (all three methods); (5) Big Three aggregated number (%) of all AFV-related patents (all three methods); (5) idem regarding outsiders' patents (only visual examination and correlation analysis); (6) AFV market share (all three methods); and (7) Electric Drive Vehicle[151] (EDV) market share (only visual examination and correlation analysis). The remaining series will be briefly referred to in the visual examination, and more prominently in the case study narrative.

VII.2.2. Sources for the qualitative case study (narrative)

While this quantitative approach shall allow for the identification of general patterns (structural break analysis and visual examination) and levels of association (correlation analysis), I will not attempt to infer definitive causal relationships. To identify deeper causal mechanisms, I will triangulate the findings with the longitudinal qualitative case study, which analyses interactions and processes in the institutional and task environments through a narrative.

Primary sources for developments in civil society are articles from newspapers and magazines (*New York Times*; *Wall Street Journal*; *Washington Post*; *Economist* etc.). I also draw on National Research Council's and governmental reports (EPA, CARB, DOE, NHTSA), industry journals (*Ward's Automotive*; *Automotive News*), and publications by automakers and their trade association (financial reports; press releases; websites; advertisements; technical papers etc.).

In addition, I build on secondary accounts of different dimensions of climate change and the car industry: science, environmental movement and public opinion (Agrawala, 1998a; Agrawala, 1998b; Corfee-Morlot *et al.*, 2007; McCright and Dunlap, 2010; Rothenberg and Levy, 2012); policy and legal developments (Meltz, 2007; Duffield *et al.*, 2008; Meltz, 2008); corporate cultural and political strategies (Doyle, 2000; Luger, 2000; Kolk and Levy, 2001); automakers' innovation strategies and technological developments (Johnson, 1999; Mondt, 2000; Abeles, 2004; Kemp, 2005; MacCormack, 2005; van den Hoed, 2005; Hekkert and van den

[151] The EDV category comprises fuel cell vehicles (FCV), hybrid-electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) and battery-electric vehicles (BEV).

Hoed, 2006; van den Hoed, 2007; Bakker and Van Lente, 2009; Bakker, 2010; Bakker *et al.*, 2012a; Bakker *et al.*, 2012b; Budde *et al.*, 2012; Lutsey, 2012; Dijk *et al.*, 2013); broader industry contexts and financial dimensions (Ingrassia, 2010); environmental challenges facing the car industry (Sperling and Gordon, 2009). Drawing on various primary and secondary sources I aim to develop a comprehensive multi-dimensional analysis of the climate-change problem and the American car industry responses.

VII.3. QUANTIFICATION APPROACH: ANALYSIS OF ATTENTION INDICATORS

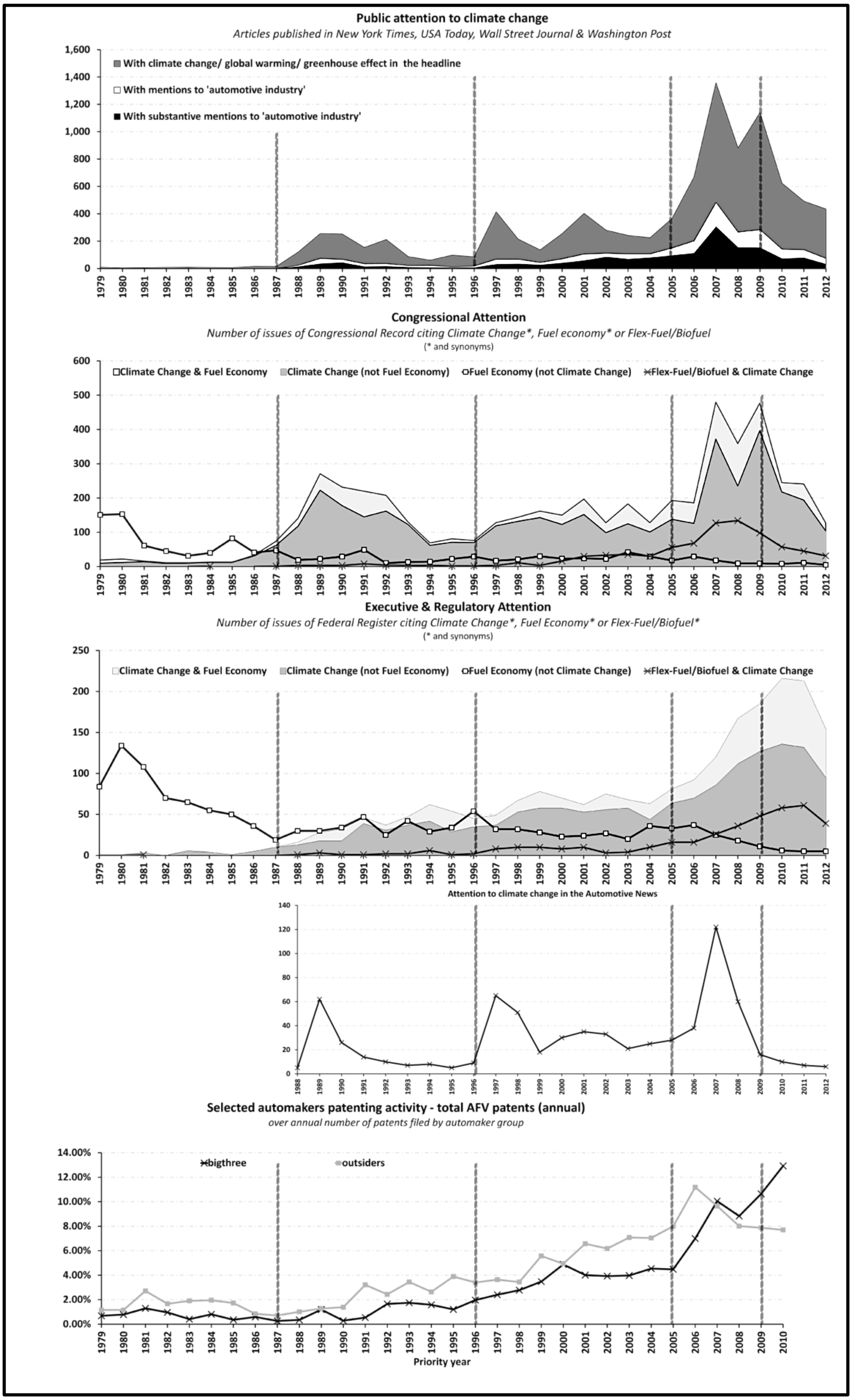
VII.3.1. Exploratory visual examination

Figure VII.2 present time-series for: (a) public attention to climate change; (b) Congressional attention; (c) executive and regulatory attention; (d) Automotive News attention to climate change; and (e) aggregated Alternative Fuel Vehicle (AFV) patents by the Big Three and regime outsiders (other manufacturers). Figure VII.3 presents time series for: (a) Automotive News attention to specific technologies; (b) Big Three patenting of specific AFV technologies; (c) regime outsiders patenting of specific AFV technologies; (d) market share of AFV; and (e) market share of EDV.

- Public attention to climate change (Figure VII.2.a) shows a period of 'non-attention' that lasts until about 1987-8. Then follows a period of moderate attention that seems associated with political developments (Senate Hearings on Climate Change in 1988, when the *New York Times* reported that "Global Warming has begun"). A peak in attention coincides with the Kyoto Conference in 1997; followed by another peak that seems connected to President Bush (Jr.) rejection of the Kyoto Protocol in 2001. From 2005 onwards, public attention to climate change surges, reaching a peak in 2007 and a low in 2009. This was a period of many symbolic events, such as the premiere of the Hollywood blockbuster *The Day After Tomorrow* (2004); the 2005 G8 meeting in Scotland, where UK Prime Minister Tony Blair declared climate change to be top priority; Hurricane Katrina (2005), and the Nobel Peace Prize to Al Gore and the IPCC. Thereafter, attention to the issue subsides, likely due to the Great Financial Crisis.

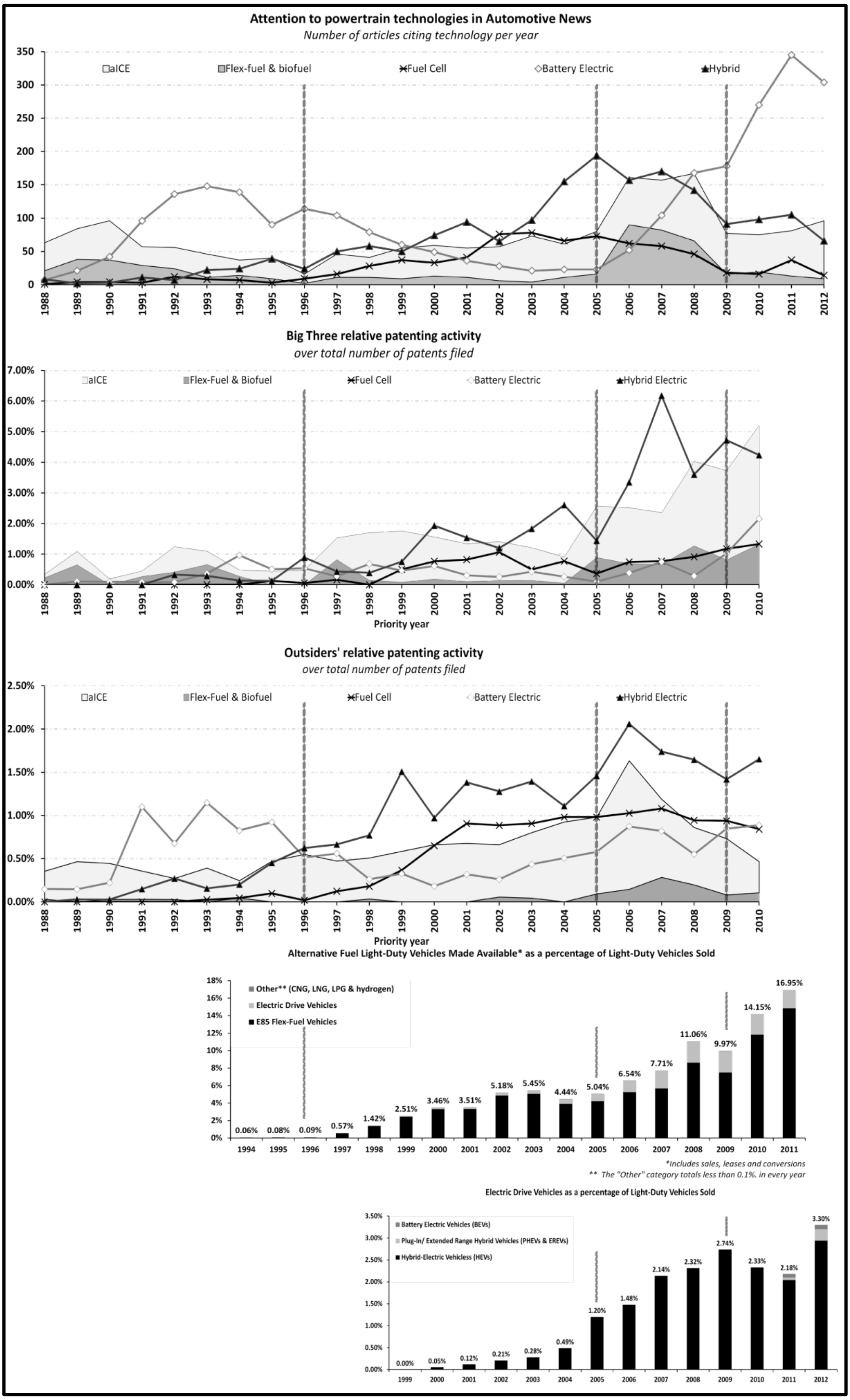
- Congressional attention to climate change (Figure VII.2.b, area plots) show similar trajectory as public attention (with the exception of the public attention peaks of 1997 and 2001). Congressional attention also begins to slowly rise before public attention, which may be related to the publication of two (contradictory) governmental-sponsored reports on climate change (1983) and a public letter (1986) by Senator Al Gore (and others) calling for action to tackle the issue. The mid-to-late 2000s also saw the enactment of two energy security legislations (2005 *Energy Act* and 2007 *Energy Security and Independence Act*) that established biofuel production and use goals. Their approval were somehow influenced by climate change discussions (Yergin, 2011), and we see a ‘hump’ in the curve depicting attention to flex-fuel/biofuel and climate change in Figure VII.2.b. Finally, if in the first few years ‘fuel efficiency’ was disconnected from climate change, throughout the period, it became part of the debate on the issue.
- Executive and regulatory attention to climate change (Figure VII.2.c, area plots) displays a trajectory much different from public and Congress attention. Although there is some executive attention beginning in the mid-1980s, it shows a very slow increase until the mid-2000s. In 2007, two key events influenced regulatory and executive attention: the US Supreme Court decided that it is EPA’s responsibility to regulate GHG emissions from cars, and President Bush (Jr.) gave a State of the Union address calling for cuts in carbon emissions. Executive attention to biofuels increases after the energy laws were enacted; and, as in Congressional attention, ‘fuel efficiency’ became increasingly part of the climate change debate (particularly after 2008).

Figure VII.2 (a-e, top-down): Attention to climate change in the US and AFV patents



Source: Author's construction based on data defined in Section VII.2.1

Figure VII.3 (a-e, top-down)*:* Attention, development and diffusion to/of AFV types



Source: Author's construction based on data defined in Section VII.2.1

- Automotive News attention to climate change[152] shows three distinctive peaks that seem associated with the peaks in public attention. However, some important events might have further influenced the industry attention: the establishment of the 'Zero-Emission Vehicle' (ZEV) mandate in California in 1990; the establishment of the public-private initiative US *Partnership for a New Generation of Vehicles* (PNGV); and the first CAFE (Corporate Average Fuel Economy) standard rise in 32 years, mandated by the 2007 Act.
- Patenting of AFV technologies, both by outsiders and the Big Three, began to slowly rise in the late-1980s/1990s (possibly connected to the ZEV mandate, and the PNGV), and picks pace in 2005 (when there were multiple AFV technologies competing for supremacy). The steady rise in patenting throughout the period seems to indicate increasing industry concern with climate change. In relative terms, outsiders' patenting has been higher than the Big Three's, until 2007 (which may be due to the CAFE rise).
- Figure VII.3.a, b and c seem to confirm the occurrence of various technology hype-cycles, although these are not as clean as represented in Figure VII.1. Based on these, I distinguish five overlapping technology attention-cycles ('hypes'): 1st BEV hype (1988-early-2000s); HEV hype (2001-2009); FCV hype (1995-2009); biofuel hype (2006-2009) and new BEV hype (2005 onwards).
- The hype-cycles ('ups and downs') are more apparent in the *Automotive News* attention graph (Figure VII.3.a) than in the patent graphs (Figure VII.3.b and c). This suggests that technological development may continue after attention 'bubbles' have burst. The qualitative case study will further analyse the drivers of various hype-cycles and their influences.
- Industry attention and technology strategy towards flex-fuel vehicles and biofuels increased substantially by 2005 (Figure VII.3.a and b). Patenting activity, however, increased relatively less than industry attention, which seem to indicate that biofuels and flex-fuels were incremental innovations (requiring some tinkering with ICE, but no substantial redesign). The relatively low degree of biofuel patenting is even more striking considering that biofuels/flex-fuels have reached some degree of market penetration (Figure VII.3.d). This could

[152] Please note that the Automotive News database in *Nexis* only starts in 1988.

indicate that this particular incremental technology did not require much new development.

- Incremental improvements with aICE[153] (Figure VII.3.b and c) have been pursued throughout the entire period, and increasingly so since the mid-1990s. The strategy accelerated in the early 2005, indicating a 'sailing ship' effect[154] (Ward, 1967; Tidd *et al.*, 2005), whereby threats from radical technologies stimulate old technology improvements.
- By 2010, there is substantial patenting activity for all technical options, which suggests that firms remain uncertain about which powertrain option will prevail, and therefore adopt a hedging strategy.
- Despite the attention and patenting in electric drive vehicles (EDV), Figure VII.3.d (and e) show that actual market diffusion is dominated by biofuel and flex-fuel vehicles (FFV). In later periods, electric drive vehicles only constitute a few percentage of the total market, which may make automakers reluctant to abandon ICE vehicles – unless EDV sales continue to accelerate. Yet, automakers prefer biofuels and FFV because these help them gain fuel efficiency credits and because these incremental innovations protect ICE-related core competencies.

VII.3.2. Testing for unknown 'structural breaks'

To determine periods and break points (already represented in the figures with vertical dotted lines), I triangulated the visual analysis with the QLR-test for structural breaks. This shall enable a more objective assessment of the visual examination method and its appropriateness for defining sub-periods in an empirical issue life-cycle. The results (breaks) are presented in Table VII.2 (see Appendix I.2 for the statistical results), in which I have linked the break years to the key events referred to in the visual examination. The results indeed seem to confirm the visual inspection of attention charts. Thus, based on these results and the visual examination exercise, I distinguish five periods:

[153] This incremental technology also received a relatively stable level of attention from the industry (Figure VII.3.a).
[154] Mendonça (2013) has recently challenged the notion that sailing ships improved performance when they faced competition from steam ships; the author found out that modernization of sailing ships happened before steamships became real competitors in trade transportation.

- 1979-1987, when climate change had low salience;
- 1987-1996, moderate public and political attention, and some patenting activity;
- 1996-2005, gradual rise in public attention, political attention, and patenting;
- 2005-2009, rapidly increasing public and political attention, accelerated patenting and HEV sales;
- 2009-2012, declining public and political attention because of the financial crisis, stagnating HEV-sales, high executive (regulatory) activities, and increasing patenting.

Table VII.2: *Results of QLR tests for structural breaks and key events in the climate change issue life-cycle*

	Breaks	Key events
Public attention to climate change	1987+ 1996+ 2004** 2005* 2006-7***	1988: NYTs announces 'Global Warming has begun' 1997: Kyoto Protocol 2004: Hollywood's *Day after tomorrow* 2005: G8 meeting in Scotland and Hurricane Katrina 2007: Nobel Peace Prize to IPCC and Al Gore
Congressional attention to climate change	1983* 1985-6* 1996*** 2006+	1983: Publication of government sponsored reports on climate change 1986: Letter by Senator Al Gore 1988: Senate Hearings on Global Warming 1997: Kyoto Protocol 2005: Energy Act 2007: Energy Independence Act
Executive attention to climate change	1985* 2007*	[1985: Discovery of ozone hole] 2007: Supreme Court's decision on EPA responsibility to regulate GHG emissions from cars; President Bush (Jr.) State of the Union address calls for emissions cut
Automotive News attention to climate change	1990+ 1993+ 1995+ 2007+	1990: ZEV mandate enacted in California 1993: Partnership for a New Generation of Vehicles (PNGV) Mid-1990s: industry denying climate change 2007: CAFE standards to rise for the first time in 32 years (Energy Security and Independence Act)
Big Three AFV patents	1988+ 1995+ 2005+	Late-1980s: GM develops BEV model *Impact* 1993: PNGV 2005: rise in bio-fuel/flex-fuel patents Mid-2000s: multiple technology hype-cycles, Big Three catching up with HEV technology
AFV market share	1996* 2005+ 2007+	1996: surge in flex-fuel/ethanol (E85) vehicle sales Mid-2000s: consolidation of HEV market niche 2007: Peak in HEV sales

*Legend: *Significant at 1% level; **Significant at 5% level; ***Significant at 10% level; +Insignificant local peak of QLR statistic*

VII.3.3. Meta-analysis of correlations within a temporal bracketing framework

The meta-analysis of correlation will use the break points as inputs. I will however use an additional analytical strategy: besides looking into within sub-periods correlations, I will look for differences between correlations before and after breaking points. Because of this thesis focus on technology developments I will concentrate on correlations between Big Three patenting and the other indicators (Table VII.3), and only mention some other interesting correlation patterns that either confirms or negate the exploratory visual analysis (full results are presented in Appendix I.3).

- Before 1988[155], Big Three patenting activity, which is very low (Figure VII.3.e), is not significantly correlated to any proxy variable (i.e. public, congressional and executive attention). [In fact, before 1988, no indicator is correlated with any other (cf. Appendix I.3).] After 1988, it becomes significantly correlated to all other, but strongly and significantly so, in particular, with outsiders' patenting and executive attention. This indicates that industry technological development activities (of incremental nature, Figure VII.3.b) started already after the first peak in attention in 1988. This seems in line with phase 2 of the DILC-model.
- But in the next period, 1988-1996, Big Three patenting is only significantly correlated to outsiders' patenting, which seems to indicate some kind of technological competition. While, overall patenting activities are still low (Figure VII.2.e), there is some attention to BEV (Figure VII.3.a) and some patenting of BEV technologies (Figure VII.3.b and c). The case study will show that these developments were connected to California's ZEV mandate. In this second period, public and congress attention become strongly (0.9667) and significantly correlated, which seems to indicate similarities between the second period and the model's *phase 2* (corroborating the visual analysis). Therefore, the early competition between regime actors and outsiders would configure a deviation from the model.

[155] Before 1988, no indicator is correlated with any other. In the next period, 1988-1996, only public and congress attention and outsiders' patenting and executive attention are strongly (0.9667) and significantly (1%) correlated.

Table VII.3: Summary of results of meta-analysis of correlations

		Before 1988	After 1987	Before 1997	After 1996	Before 2005	After 2004	Between 1987 & 1997	After 1996	Between 1996 & 2005	After 2004
Big Three patents vs. Public attention	*Spearman's rho*	-0.5188	0.7213	0.0702	0.6923	0.5567	0.3714	-0.6000	0.6923	0.0000	0.3714
	Sig.	insig.	*	insig.	*	*	insig.	***	*	insig.	insig.
	Obs.	9	23	18	14	26	6	9	14	8	6
	Sig. Difference?							*			
Big Three patents vs. Congress attention	*Spearman's rho*	-0.3193	0.3551	0.0692	0.7528	0.3261	0.5429	-0.6167	0.7528	0.2684	0.5429
	Sig.	insig.	***	insig.	*	insig.	insig.	***	*	insig.	insig.
	Obs.	9	23	18	14	26	6	9	14	8	6
	Sig. difference?							*			
Big Three patents vs. Executive attention	*Spearman's rho*	-0.5085	0.9098	0.3650	0.7934	0.7548	0.9429	0.4833	0.7934	0.1190	0.9429
	Sig.	insig.	*	insig.	*	*	*	insig.	*	insig.	*
	Obs.	9	23	18	14	26	6	9	14	8	6
	Sig. difference?					insig.					
Big Three patents vs. Automotive News attention	*Spearman's rho*			-0.2427	-0.2308	0.2379	-0.4286	-0.2427	-0.2308	-0.4286	-0.4286
	Sig.			insig..	insig.	insig.	insig.	insig.	insig.	insig.	insig.
	Obs.			9	14	17	6	9	14	8	6
	Sig. difference?										
Big Three patents vs. Outsider's patents	*Spearman's rho*	0.5500	0.9042	0.6821	0.7407	0.8708	-0.6000	0.6000	0.7407	0.5476	-0.6000
	Sig.	insig.	*	*	*	*	insig.	***	*	insig.	insig.
	Obs.	9	23	18	14	26	6	9	14	8	6
	Sig. difference?			insig.		*		insig.			
Big Three patents vs. AFV market share	*Spearman's rho*					0.8273	0.8286			0.5714	0.8286
	Sig.					*	**			insig.	**
	Obs.					11	6			8	6
	Sig. difference?					insig.				insig.	
Big Three patents vs. EDV market share	*Spearman's rho*					0.2571	0.8857				
	Sig.					insig.	**				
	Obs.					6	6				
	Sig. difference?										

Source: Author's construction based on results presented in Appendix I.3 and significance tests for difference between correlations.

- Between 1997 and 2005, correlations between Big Three patenting and the other variables are not significant. The narrative study will show that this was a period of regulatory uncertainty. It is yet interesting to highlight the association between outsiders' patenting and the AFV market share (cf. Appendix 1.3), which is the only significant – and strong (0.8810) – correlation in the period. This seems to indicate early technological innovation by outsiders, in line with the model's phase 3. Indeed, this is the period when Japanese manufacturers started selling hybrid-electric vehicles in the US market.

- After 2005, Big Three patenting activities become significantly and strongly (0.9429) correlated with executive attention and the AFV (0.8286) and EDV (0.8857) market share. This seems to indicate an important turning point in the climate change issue life-cycle, whereby dynamics affecting the task environment becomes more important than those from the institutional environment. As discussed in the visual examination, the energy acts of 2005 and 2007, and, in particular, the 2007 Supreme Court decision represent important events leading to these new dynamics. Indeed, from 2005 onwards, correlation between executive attention and AFV market share becomes significant and strong (0. 9286). However, this is not the case for the association between executive attention and EDV market share[156], so that the correlation appears to capture the push for biofuels after the energy acts.

Throughout the whole period, the association between patenting and public attention is highest after 1987; between patenting and congressional attention is highest after 1996; and between patenting and executive attention is highest after 2005. This shows a very interesting dynamic that confirms the sequential view of the DILC-model, in which the industry first responds to pressures from civil society; then to policy-making (Congress); and later to developments at the executive level (policy implementation). The correlation analysis is therefore very much in line with the overall logic of the DILC-model.

The quantification approach and, in particular, my interpretation of the correlation results, pointed to some tentative inference about causality. However, correlation does *not* imply strict causality, and – even though the analysis takes into account the size of the sub-samples – the power of the statistical tests is not very high (Kenny, 1987). Therefore, these results will be confronted with the in-depth narrative, in order to unveil deeper causal mechanisms.

[156] Which are medially correlated (0.7381, significant) at the 5% level.

VII.4. QUALITATIVE APPROACH: IN-DEPTH NARRATIVE

I now turn to the qualitative case study of the different periods. Based on the initial quantitative analysis, I divided the case into five periods: 1979-1987; 1987-1996; 1996-2005; 2005-2009; and 2009-2012. Using the DILC-model as an ideal-type, and according to the case study protocol, I describe for each period: (1) problem-related pressures (from science, social movements, public opinion, policy-makers, consumers, outsiders etc.); (2) response strategies from the car industry; and (3) broader developments in task or institutional environments that (positively or negatively) influence life-cycle dynamics or industry strategies. As in the safety case study, to guide the reader, here I also adopt the strategy of starting each period with a discussion of the match or mismatch with the conceptual phase-model.

VII.4.1. Problem emergence, sense-making and industry indifference (1979-1987)

This period displays dynamics that fit well with DILC's phase 1: (a) sense-making processes regarding climate change; and (b) environmentalists (and scientists) engaged in attention advocacy. One minor deviation is thus that a mass social movement is already present (while in the DILC-model activists coalesce into a social movement in phase 2), because the environmental movement was already institutionalized (Dunlap and Mertig, 1992). Other is the presence of early symbolic action in the policy domain (e.g. government-sponsored reports in 1983), with some acting as issue-advocates (e.g. Senator Al Gore in 1986).

VII.4.1.1. Pressures around issue

Science, social movements, public opinion. In the 1970s, climate change emerged as a scientific research topic (Yergin, 2011; Carey, 2012). A series of scientific meetings, conferences and workshops provided the stage for academic sense-making and debates (Agrawala, 1998a), e.g. the *World Climate Conference* (1979) and the Villach and Bellagio meetings (1987). Researchers began calling for political action to develop *responses* to climate change (Corfee-Morlot *et al.*, 2007).

The environmental movement, which had emerged in previous decades with a focus on addressing local problems (smog, water pollution), shifted attention to global issues such as climate change (Dunlap and Mertig, 1992; Corfee-

Morlot *et al.*, 2007) and began calling for measures to tackle global warming (Corfee-Morlot *et al.*, 2007).

Public attention to global warming remained low (Figure VII.2.a) because environmental news was dominated by other issues such as nuclear energy, acid rain and the ozone hole[157] (Corfee-Morlot *et al.*, 2007; Dunlap and Mertig, 1992). Additionally, the economic recession of the early 1980s dampened public attention to environmental issues (Dunlap, 1992).

Policy-makers. Political activity was symbolic and aimed at sense-making. The 1978 *National Climate Act* dedicated $50 million[158] of annual budget to research funding (Rothenberg and Levy, 2012). In 1980, the Senate held hearings to understand the problem of climate change (Corfee-Morlot *et al.*, 2007). In 1983, reports from the US Environmental Protection Agency (EPA) and the National Academy of Sciences (NAS) reached conflicting conclusions regarding the need for action (Corfee-Morlot *et al.*, 2007). This reflected scientific uncertainty, which may be connected to the lack of issue-salience before public opinion. Senator Al Gore however acted as a policy entrepreneur and engaged in attention advocacy when he and others wrote a public letter (1986) declaring to be 'deeply disturbed' about climate change and calling for policy action (Yergin, 2011).

VII.4.1.2. Car industry issue responses

The car industry – and businesses, in general – was unconcerned with climate change (Rothenberg and Levy, 2012), thus remaining in its 'zone of indifference'. Automakers were more engaged with local air pollution, emission standards and the development and implementation of the three-way catalytic converter (see Chapter V).

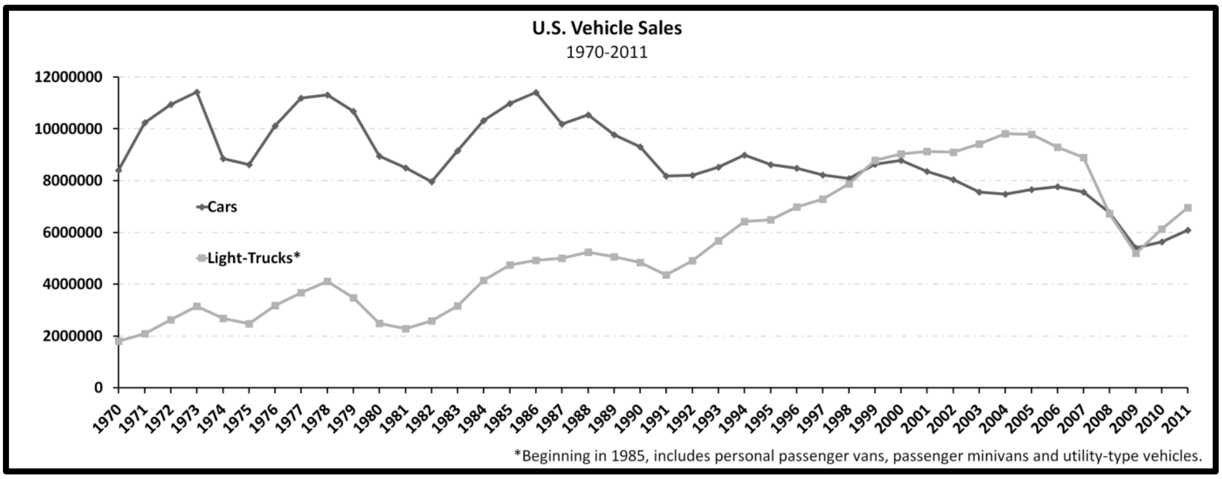
VII.4.1.3. Influences of broader industry contexts on issue life-cycle

Two broad industry developments would shape future responses of American automakers to climate change. The first development was the opening up of a new market segment, which started with Chrysler's *Minivan* (1984MY), and morphed into Sports Utility Vehicles (Ingrassia, 2010). This market segment, which commanded high profit-margins (Doyle, 2000), was purposively designated as

[157] Discovered by British researchers in 1985.
[158] $ 176 million in 2012 dollars.

'light-trucks' (i.e. supposedly for commercial purposes), because this category was subject to more lenient fuel economy standards (Luger, 2000). The light-truck segment would dominate the American car market in future decades (Figure VII.4).

Figure VII.4: In the early 1980s, sales of trucks began an upward trajectory until, in 1999, more trucks than cars were sold in the American market

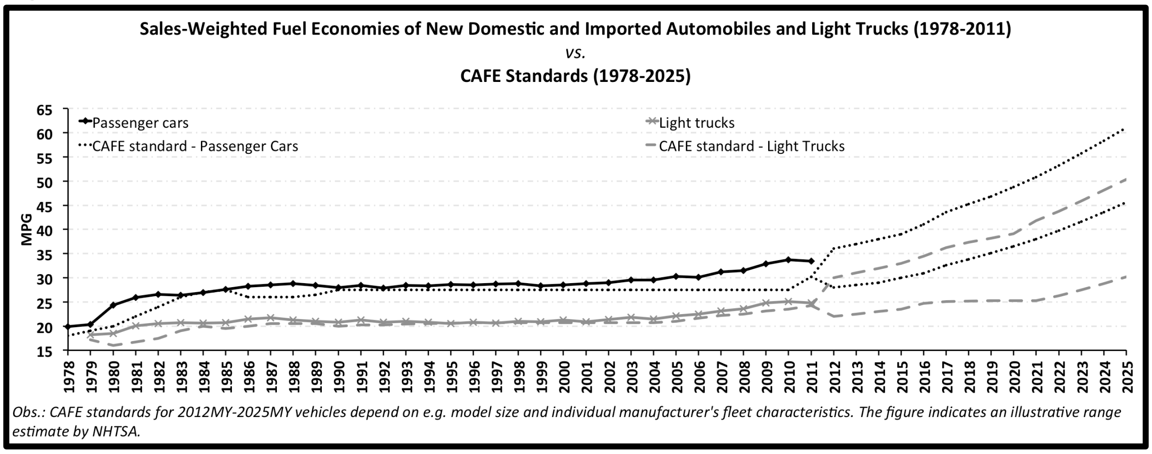


Source: Author's construction based on data from US EPA (2012)

A second development was the introduction of fuel economy regulations, which were enacted in 1974 to save fuel amidst the energy crisis. The CAFE (Corporate Average Fuel Efficiency) standards started at 18 mpg for 1978 models and would increase to 27.5 mpg in 1985 (Figure VII.5). GM and Ford initially intended to comply by downsizing part of their fleet, while Chrysler invested US$5 billion in fuel-efficient internal combustion engine technologies (front-wheel drive, lighter parts, turbocharged four-cylinder engines)[159]. But as the expanding light truck market became the industry's cash cow (Ingrassia, 2010), their innovation and economic positioning strategies increasingly focused on big, gas guzzling vehicles (Doyle, 2000). When this created problems in meeting the CAFE standards, GM and Ford lobbied the NHTSA (National Highway and Traffic Safety Administration), responsible for the implementation of the standards, which relaxed them to 26 mpg for 1986-1988 models, and 26.5 mpg for 1989 models, with the 27.5 mpg requirement postponed to 1990 (Figure VII.5).

[159] While not displayed in Figures VII.3.b, I also collected data for pre-1988 years. It shows that in the pre-1988 era, the majority of AFV patents fell in the aICE category, which is in line with Doyle's (2000) claims.

Figure VII.5: CAFE standards and fuel economy of new cars



Source: Author's construction based on data from NHTSA (2011) and USEPA and NHTSA (2011)

VII.4.2. Rising public concern and the creation of a closed industry-front (1987-1996)

This period displays the following dynamics: (a) increase in public attention; (b) symbolic political engagement at the Federal and global level; (c) creation of a closed industry-front. This seems in line with the model's phase 2. In some respects, however, the period deviated from the ideal type: (1) at the state level, California's Zero Emissions Vehicle (ZEV) mandate formed a strong piece of regulation that created substantial pressure on the car industry; (2) symbolic political engagement soon became hot political debate; and (3) there was an early innovation race on a radical innovation (BEV), triggered by an incumbent firm (GM).

VII.4.2.1. Pressures around issue

Science, social movements, public opinion. The late-1980s were hot years (with record-high temperatures and droughts), which stimulated public attention to global warming (Figure VII.2.a). Public attention was also stimulated by the 1988 Senate Hearing on global warming (see below) and by framing struggle between scientists/environmentalists and climate-sceptics supported by businesses (Doyle, 2000; Luger, 2000). By 1989, the percentage of Americans who had heard of the 'greenhouse effect' had more than doubled in relation to 1981, reaching almost 80% according to one survey (Corfee-Morlot *et al.*, 2007). With increased public sensibility, attention to global warming grew sharply in 1988-1990, with the car industry also implicated in the issue (Figue VII.2.a). The newly created (1988) *Intergovernmental Panel on Climate Change* (IPCC) also stimulated the public profile of climate change with comprehensive assessment reports (in 1990 and 1996), which reviewed, assessed and integrated scientific findings of risk, potential consequences and possible mitigation options (Corfee-Morlot *et al.*, 2007).

Policy-makers. Political action occurred at multiple levels. At the global level, symbolic action dominated. The 1988 *Toronto Conference on Changing Atmosphere* was the first international meeting of western governments to call for restrictions in GHG emissions. The first IPCC report (1990) provided the basis for international negotiations, which resulted in heads of state signing the *United Nations Framework Convention on Climate Change* (UNFCCC) at the 1992 *Rio Earth Summit* (Corfee-Morlot *et al.*, 2007). Although Rio 1992 established the goal of stabilizing GHG concentrations at a level that would prevent 'anthropogenic climate change', its result was more symbolic than substantive, as the Framework was a voluntary, non-binding agreement that would prove elusive to implement (Kolk and Levy, 2001; Yergin, 2011). In 1995 (Berlin), signatory parties established a differentiated responsibility approach: industrialized nations were to agree on specific targets and timeframes, but not developing countries (Corfee-Morlot *et al.*, 2007). In 1996 (Geneva), the parties accepted the findings from the second IPCC assessment report, and called for legal-binding targets and timeframes (Agrawala, 1998b). At this meeting, the US Delegation actively pushed for the adoption of more stringent measures in the following (1997) meeting in Kyoto (Johnston, 1997).

At the US Federal level, the 1988 Senate hearings were a key event, especially the testimony of NASA climate scientist, James Hansen, on a very hot day (Yergin, 2011). Hansen linked the hot summer to global warming, something which the mass media keenly reported. The *New York Times*' front page (24/6/1988), for instance, warned that: 'Global Warming has begun' (Shabecoff, 1988). The 1988 hearings "mark[ed] the emergence of climate change as a political issue" (Yergin, 2011, p. 453). Political debate ensued. A proposal was subsequently made to embed global warming in the *Federal Clean Air Act*, which was under Congressional revision in 1989-1990 (Doyle, 2000; Duffield *et al.*, 2008). But this proposal failed to be enacted. Proposals were also made to use fuel economy legislation as a way to address global warming (Doyle, 2000; cf. Figure VII.2.a).

Politicians soon began jockeying for the fatherhood of a 'global warming act' and proposed bills that incorporated automotive fuel economy provisions

(Doyle, 2000): the *Global Warming Prevention Act* (which included a fuel efficiency mandate of 45 mpg for cars and 35 mpg for trucks by 2004); the *National Energy Policy Act*; the *World Environment Act* (sponsored by Senator Al Gore); the *Global Environmental Protection Act* (calling for a 50% reduction in automotive carbon emissions, equivalent to a fuel economy standard of 55 mpg); and the so-called *Bryan Bill* (focused exclusively on fuel economy to address global warming). But all these bills failed to pass because of strong corporate opposition (see below). The 1989 *Bryan Bill*, for example, which proposed a 20% increase in CAFE standards by 1995 and 40% by 2001 (equivalent to about 40 mpg), was publicly opposed by automakers. President Bush (Sr.) subsequently threatened to veto it (Doyle, 2000), because he preferred a voluntary approach through public-private partnerships (PPP) aimed at developing advanced technologies and the promotion of alternative (mainly ethanol/methanol) fuels (Duffield *et al.*, 2008; Yergin, 2011) (see below). The bill was not voted in 1990, and a reintroduced version died in 1991, because of coordinated opposition from automakers and 'astroturf' organizations (Doyle, 2000).

Thereafter, political action at the Federal level moved away from regulation and towards a conciliatory approach through PPPs (Luger, 2000). The newly elected (1993) president Clinton took similar voluntary approach and established another PPP with Detroit automakers (*Partnership for a New Generation of Vehicles*, see below). In return for industry participation, he offered a moratorium on mandated fuel economy increases (Luger, 2000) (cf. Figure VII.5). The Clinton administration did, however, take a leading role in international climate change negotiations in Berlin (1995) and Geneva (1996) (Johnston, 1997).

At the US state level, California's 'Zero-Emission Vehicle' (ZEV) mandate (1990) was a strong piece of legislation that required the seven biggest automakers in California to sell a fleet mix that included different categories of vehicles according to increasingly stringent emission levels (Table VII.4), setting a tough fine (US$5,000[160]) per non-compliant vehicle (Kemp, 2005). The plan was in effect a 'sales mandate' for BEVs (Kemp, 2005), because "battery-powered electric vehicles [were] the only zero emission automotive technology on the horizon" (Doyle, 2000, p. 274). The introduction of the ZEV-mandate was influenced by GM's unveiling of

[160] C. $8,800 in 2012.

a BEV prototype (see below). By 1994, other states were considering adopting the Californian ZEV mandate, which led the Big Three to start an intense lobbying campaign against this development (Doyle, 2000). The ZEV-regulation also established a biannual review process, which offered carmakers an opportunity to shape the policy process. While the original regulation survived the first two reviews (1992 and 1994), CARB (California Air Resources Board) dropped the 1998-2002 requirements in 1996 under great pressure from automakers (Kemp, 2005).

Table VII.4: CARB original sales requirements under the LEV/ZEV mandate

Model Year	*Conventional vehicles*	*Transitional Low Emission Vehicles (TLEV)*	*Low Emission Vehicles (LEV)*	*Ultra-Low Emissions Vehicle (ULEV)*	*Zero-Emission Vehicles (ZEV)*
1994	90%	10%	-	-	-
1995	85%	15%	-	-	-
1996	80%	20%	-	-	-
1667	73%	-	25%	2%	-
1998-2000	48%	-	48%	2%	2%
2001-2002	-	-	90%	5%	5%
2003	-	-	75%	15%	10%

Source: Kemp (2005, p. 175)

Foreign automakers. In response to the ZEV mandate and PNGV, Toyota decided to develop a car with 100% fuel economy improvement (Doyle, 2000). In 1995, Toyota decided to produce the car by December 1997, in time for the international climate meeting in Kyoto (Yergin, 2011). Honda would follow suit and announce the development of a HEV-prototype (Doyle, 2000). HEVs were initially derided by the rest of the industry, because twin-powertrains substantively increased costs. GM perceived HEVs as 'interim' technology, and decided instead to focus on fuel cells, which would "make hybrids obsolete" (MacCormack, 2005, p. 15).

More disruptive fuel cell vehicles (FCV) were initially pioneered by Daimler-Benz (Dyerson and Pilkington, 2005; Hekkert and van den Hoed, 2006). In 1994, it unveiled a cumbersome prototype, the "NECAR [New Electric Car], followed by the smaller NECAR II (1996), which "caus[ed] widespread optimism with regard to fuel cell vehicles (FCVs) among a broader range of stakeholders" (Budde *et al.*, 2012, p. 1078). Daimler thus put fuel cells 'on the map' (cf. Figure VII.3.c) as a zero-emission technology (van den Hoed, 2005).

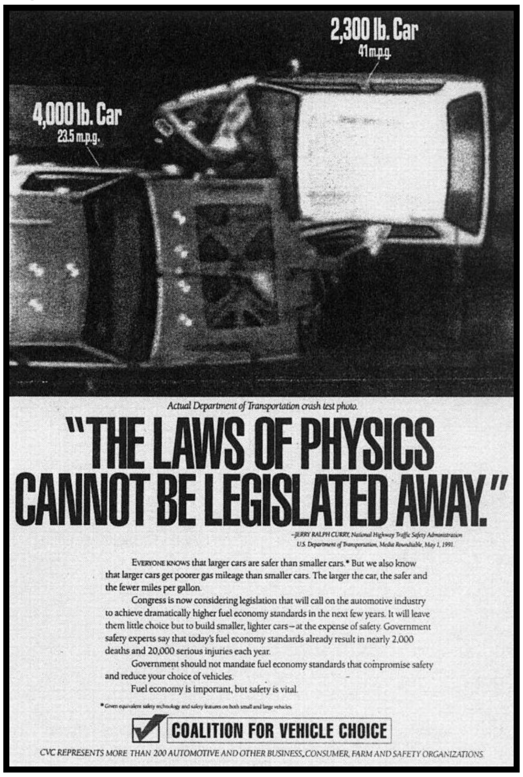
VII.4.2.2. *Car industry issue responses*

Social-cultural strategies. In 1989, the Big Three, the American Automobile Manufacturers Association[161] (AAMA), and forty other American companies and industry associations formed the *Global Climate Coalition* (GCC) (Kolk and Levy, 2001; Levy, 2005). The GCC formed a 'closed industry front' to hinder further progression of the climate change issue (Bonardi and Keim, 2005). Throughout the 1990s, the GCC commissioned reports that attacked the science behind global warming (Doyle, 2000), e.g. by accusing the IPCC of downplaying uncertainties. Individual automakers also followed this strategy, with Ford and Chrysler being "especially vociferous in the early 1990s, through speeches and editorials, in castigating concerns about climate change and emphasizing the high cost of precipitate action in the face of uncertainty" (Rothenberg and Levy, 2012, p. 41). With these information strategies, the industry "tried to confuse the public by saying global warming was based on bad science and was only theory, not fact" (Doyle, 2000, p. 387).

American automakers also set up 'astroturf' organizations – coalition building strategies – that created pressures on politicians. The supposedly 'grassroots' *Coalition for Vehicle Choice* (CVC), supported by the industry, for instance, promoted the view that stricter CAFE standards would limit vehicle choice and 'outlaw' SUVs and pick-ups (Luger, 2000). More than 200 CVC-enlisted groups (dealers, parts suppliers and their trade associations) initiated letter-writing campaigns to pressure congressmen not to enact the Bryan Bill (Doyle, 2000). CVC also sponsored newspaper advertisements (Figure VII.6) that suggested a trade-off between fuel economy and car safety, claiming that smaller and lighter cars were less safe (Luger, 2000). Consumer advocacy groups criticized this framing as misleading (Doyle, 2000) because it ignored the importance of advanced engine technologies (improved fuel-injection systems, turbo charging, advanced valve management) and innovative safety devices (airbags, high-strength/light-weight materials, anti-lock brakes).

[161] Which substituted the AMA as the main US automotive industry trade association.

Figure VII.6: CVC's 1991 ad on a supposed trade-off between fuel economy and safety



Source: Doyle (2000, p. 264)

The American car industry also attacked the Californian ZEV mandate, with the AAMA officially stating that its own strategic goal was to "[create] a climate in which the [California EV] mandate [...] can be repealed" (cited in Doyle, 2000, p. 294). Japanese manufacturers joined this attack, claiming that battery technology would not be ready for commercialization by 1998 (Kemp, 2005). When an independent *Battery Technology Advisory Panel* concluded that battery costs would still represent a barrier to EV diffusion by 1998 (Doyle, 2000; Kemp, 2005), CARB decided (1996) to drop the 1998-2002 sales requirements.

Political strategies. American automakers used *financial incentive strategies* and *information strategies* to water down Federal proposals to increase fuel economy standards and to avoid adoption of the ZEV mandate by other states. Campaign contributions and payment of personal trips incentivized politicians to vote against legislation, resulting, according to one analysis (cited in Luger, 2000, p. 160), in 'a strong correlation' between auto industry donations and Senators' votes on CAFE proposals. Information tactics included direct lobbying, reporting research results that attacked climate science, and commissioning policy proposals (Doyle, 2000; Luger, 2000; Kemp, 2005). Technological strategies through public-private partnerships also represented a kind of *political* strategy, because they improved the Big Three's legitimacy before policy-makers and the public (signalling their willingness to take action).

Innovation strategies. In this period, environmental technology strategies of American automakers focused on incremental innovations such as advanced-Internal Combustion Engine (aICE) technologies (Figure VII.3.b). These included improved fuel injection systems and lean-burn catalysts (Mondt, 2000). Another strategy to defend existing ICE technology was the development of ethanol-fuelled or flex-fuel vehicles (FFV), which were capable of running on methanol/ethanol or gasoline or a mixture of both (e.g. E85, an 85% ethanol fuel mixture). The 1988 *Alternative Motor Fuels Act* (AMFA) assigned CAFE credits to the production of FFVs (Duffield *et al.*, 2008). Automakers seized this option and focused on flex-fuel models. By 1997 almost 85,000 E85 Flex-Fuel Vehicles were sold, leased or converted, about 1% of total passenger car sales (Figure VII.3.d).

Carmakers (except GM) gave relatively little innovative attention to alternative powertrain technologies (van den Hoed, 2005). In the late 1980s General Motors dedicated some resources to radical innovation (BEV) for reputational reasons, under sponsorship of its chairman Roger Smith. The resulting prototype (the *Impact*) was meant to demonstrate that GM was not a stale, boring company, but still mustered innovative capabilities (Johnson, 1999). The *Impact* 'show-car' had several innovative features: an advanced 'teardrop' aerodynamic design, special tires to reduce drag, regenerative braking (Johnson, 1999), innovative materials such as fibreglass (Kemp, 2005), a pack of 32 lead-acid batteries, and two electric motors to drive each front wheel (Doyle, 2000).

When the *Impact* was unveiled at the Los Angeles Motor Show of 1990, it received much positive publicity. Smith then, somewhat impulsively, decided that GM would market the car (Doyle, 2000). "Ignoring advice of other executives who feared electric vehicles would not sell and might become part of California legislation, Smith publicly announced a production programme [on the 20th *Earth Day*] in April 1990" (Kemp, 2005: p. 174-5). CARB interpreted this announcement as indicating that BEVs were sufficiently developed, and issued the ZEV mandate a few months later (Kemp, 2005). Subsequently, GM created a 400-person, $300-

million EV programme (Doyle, 2000) to produce 25,000 vehicles per year by 2000 (Kemp, 2005).

Other carmakers feared that GM's initiative might spark an innovation race (in fact, Figure VII.3.c shows a significant rise in BEV patenting by outsiders in the early 1990s), provide support for the ZEV-mandate, and offer an entry point to competitors (Doyle, 2000; Kemp, 2005). In 1991, the Big Three therefore formed another closed industry-front so that all three companies would move together technologically and share the risks of developing radical innovations (Keenler, 1992). The *US Advanced Battery Consortium* (USABC) was a public-private partnership launched by President Bush and the Big Three (Doyle, 2000). Although most of the funds came from the Department of Energy (DoE), the Big Three ran the program and decided which battery developers got the grants (Doyle, 2000). The USABC fulfilled several roles for American automakers (Doyle, 2000; Luger, 2000): (a) improving their public reputation; (b) controlling technical development; (c) managing technological expectations through the establishment of unrealistic mid-term goals (such as a minimum driving range of 150-miles) "that enabled an indefinite postponement of progress" (Doyle, 2000:308); and (d) controlling the release of technical information to policy-makers to prevent that standards would be ratcheted up. According to a former GM employee, "the automakers formed USABC to hinder rather than enhance product development by controlling research and development efforts" (quoted in Doyle, 2000, p. 309).

In 1992, after suffering substantial financial losses (cf. Figure VI.17, p. 228) and after Smith's retirement, GM downscaled its BEV project to a US$32-million demonstration programme of 30-50 cars/year, with 1/3 of the initial personnel (Doyle, 2000; Kemp, 2005). GM also decided to lease its electric car, for US$33,995, about half of real costs of $78,000 (MacCormack, 2005). By 1996-7, GM leased about 760 units (MacCormack, 2005), which was far below initial expectations. Critics accused GM of deliberately under-promoting electric cars (Doyle, 2000; Sperling and Gordon, 2009). For the ZEV-mandate's third review (1996), GM, Ford and Chrysler aligned their position, publicly complaining about the state of battery development, low consumer demand, and lack of infrastructure (Johnson, 1999): "the automakers joined together to insure that none of them separately would go out ahead of the others – although GM clearly had the technological lead" (Doyle, 2000, p. 322).

Another technological project that provided 'political cover' (Doyle, 2000) to the American automakers was the 1993 *Partnership for a New Generation of Vehicles* (PNGV). This $300-million joint-venture with Federal research laboratories aimed at developing a 'production prototype' by 2003, capable of reaching a fuel economy of c. 80 mpg, without sacrificing on size, performance or safety (Doyle, 2000). PNGV served similar purposes as USBAC: directing technical developments, controlling technological expectations and playing on information asymmetries. In exchange for their participation the Big Three also secured a moratorium on Federal CAFE increases (Doyle, 2000). The Big Three also used the PNGV to pre-empt regulatory action, claiming that self-regulation and PPP was more effective than 'command-and-control' regulations (Doyle, 2000).

Although PNGV developed some radical technologies that would later become innovations (e.g. lightweight materials, lithium-ion battery cell, fuel-flexible processors for a fuel cell) (National Research Council, 1997), the Big Three directed most research efforts towards incremental technologies for advanced diesel engines (e.g. lean-burn NO_x catalysts, diesel direct fuel injection systems) and (diesel) hybrid powertrains (Mondt, 2000). The preferred option for reaching the 2003 80-mpg target was the '4SDI' engine technology, a four-stroke, direct injection diesel with 40% better fuel economy than conventional petrol engines (Doyle, 2000). But since diesel engines did not meet NO_x or particulate matter emission standards, they could not be deployed until diesel catalytic converters were substantially improved (Mondt, 2000; National Research Council, 1997).

Market positioning strategies. Despite changes in regulatory frame conditions and pressures from the task environment, consumer demand for AFVs was almost inexistent, so that climate change hardly affected American automakers' market positioning strategies. In fact, American automakers were firmly oriented towards selling profitable light trucks.

VII.4.2.3. Influences of broader industry contexts on issue life-cycle

The climate change issue life-cycle was hindered by the economic recession of early 1990s, which changed the priorities of the Big Three. American automakers experienced major financial problems as light-duty vehicle sales plummeted 13% in 1990 and did not grow in 1991 (Figure VII.4). GM reported financial losses of $5.0 billion in 1991 and $25.7 billion loss in 1992 (cf. Figure VI.17, p. 228), which also related to additional expenditures for pension fund commitments (Ingrassia, 2010). Ford and Chrysler also experienced major losses in the early 1990s (cf. Figure VI.17, p. 228). These financial problems overshadowed attention to climate change, and exacerbated the automakers' unwillingness to invest in fuel efficiency technologies (Luger, 2000).

Climate change life-cycle evolution was also hindered by the boom of the light-truck market after 1993 (Luger, 2000) (Figure VII.4). This lucrative market improved the financial situation of the Big Three (cf. Figure VI.17, p. 228), who perceived climate change as a potential threat to this market segment. In fact, the development of this segment resulted in a type of 'rebound effect' (cf. Small and van Dender, 2007; also Sorrell and Dimitropoulos, 2008), because "any technological improvements on the fuel efficiency front were being more than offset by increasing weight of vehicles and larger engine sizes" (Levy and Rothenberg, 2002, p. 179).

VII.4.3. Political stalemate and defensive hedging (1996-2005)

In this third period, (a) public attention to climate change further increased; (b) specialist expertise was elaborated in policy sub-systems (CARB, PNGV, USABC); (c) automakers acknowledged the problem, but opposed it politically, causing controversy and deadlock; (d) limited macro-political pressure (i.e. pressure from the legislative and the executive) because Congress and the Bush-administration opposed regulation; and (e) automakers moved towards hedging strategies, maintaining their overall commitment to aICE and biofuels/FFV, but increasing R&D investments in more radical alternatives. The period therefore present dynamics in line with DILC-model's phase 3. Yet, it also contained some deviations, because it included elements expected in phase 4: (1) the political industry front weakened as firms abandoned the GCC; (2) foreign firms (Toyota, Daimler) aimed to secure first-mover advantages with radical innovations (HEV, FCV), which 'opened up' the industry front, and triggered innovation races.

VII.4.3.1. Pressures around issue

Social movements, public opinion. Public attention increased in 1997 (Figure VII.3.a) because of the Kyoto treaty. Progressive businesses such as the *Pew Center on Global Climate Change* began to endorse the climate change issue (Rothenberg and Levy, 2012), advancing a 'win-win' discourse (Elkington, 1994), which argued that proactive climate change strategies could open up new business opportunities. It further accelerated towards the end of the period, due to (a) the launch of the blockbuster movie *The Day after tomorrow* (2004), which helped to "promote climate change from an obscure scientific issue to one of popular public concern" (Corfee-Morlot *et al.*, 2007, p. 2764); (b) the 2005 G8 meeting in Scotland, where UK Prime Minister Tony Blair declared climate change to be top priority (Yergin, 2011); and (c) Hurricane Katrina (2005), which became a powerful image of potential consequences of a changing climate

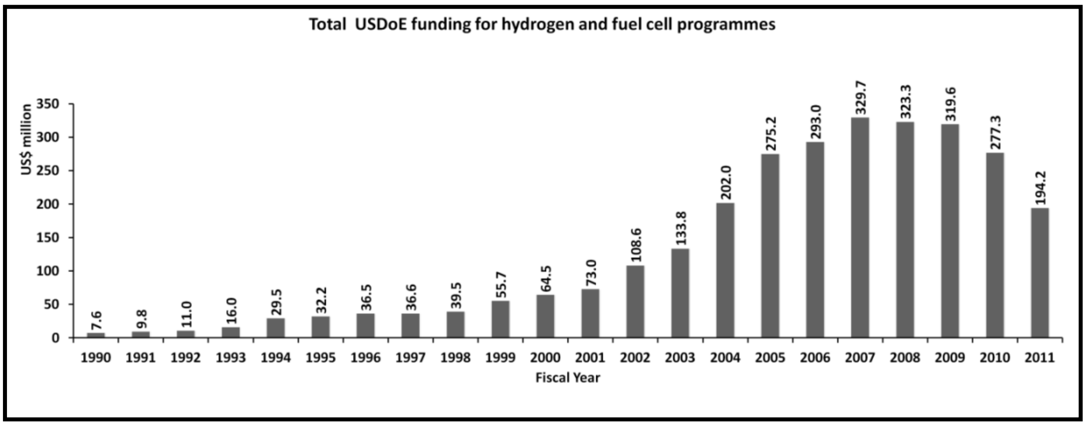
The environmental movement was seen as a legitimate actor and invited to the international climate negotiations, but environmentalists also staged protests and demonstrations (Carpenter, 2001; Corfee-Morlot *et al.*, 2007). And, in 1999, American environmental groups filed a petition (CTA, 1999) to the EPA requesting it to undertake its 'mandatory duty' of regulating new motor vehicle emissions of greenhouse gases (CO_2; methane/CH4; nitrous oxide/N_2O; and hydrofluorcarbons/HFCs). This would turn out to be the start of a decade long struggle about EPA's role in regulating GHG from motor vehicles.

Policy-makers. At the global level, the Kyoto Protocol (1997), in which many countries pledged to reduce GHG emissions by an average of 5% below 1990 levels by 2012, was a significant political step (Doyle, 2000). Although the US played a key role in the negotiations, Clinton/Gore never submitted the treaty for Senate ratification, because they anticipated rejection (Doyle, 2000). In Europe global automakers (including American subsidiaries) signed a 'voluntary' agreement (in 1998) with the European Commission to reduce average new car emissions to 140 grams of CO_2 per kilometre (c. 39MPG) by 2008-9.

In 2001, the newly elected President Bush (Jr.) rejected the Kyoto Protocol for being 'unfair and ineffective', creating regulatory stalemate at the Federal level (cf. Figures VII3.b and VII.3.c). A few US congressmen proposed legislation to address GHG emissions. Senators McCain and Lieberman, for instance, proposed a cap-and-trade system in 2003, but the bill was never voted on. Other bills also faced strong opposition (Yergin, 2011). In 2003, EPA denied the petition filed by environmental groups, arguing that EPA did not have authority under the Clean Air Act to regulate GHGs (Meltz, 2007). The State of Massachusetts (with eleven other states, three cities, two US territories, and several environmental NGOs) appealed, but the Appeals Court rejected it in 2005.

Although the government did not regulate, it stimulated technological development, particularly of a new radical option – fuel cells – with two initiatives. This indicates a shift in hype-cycles from BEV to FCV. One initiative was the 2003 *FreedomCAR and Fuel Partnership*, a public-private research programme that aimed to reduce the cost of fuel cells from \$3,000-to-\$4,000 per kilowatt hour to about \$45, a level roughly comparable to the cost of internal combustion engines (Sperling, 2003). The other was the 2004 *Hydrogen Fuel Initiative*, a \$1.2 billion research-funding project that resulted in DoE's *Hydrogen Program*. These programs, which aimed at both energy security and climate change, increased available funding (Figure VII.7), contributed to fuel-cell enthusiasm (Bakker *et al*., 2012; cf. Figure VII.3.a), and boosted hydrogen/fuel cell R&D (cf. FiguresVII.3.b).

Figure VII.7: Department of Energy (DoE) funding for fuel cell and hydrogen programmes



Source: Based on data from Peterson and Farmer (2012)

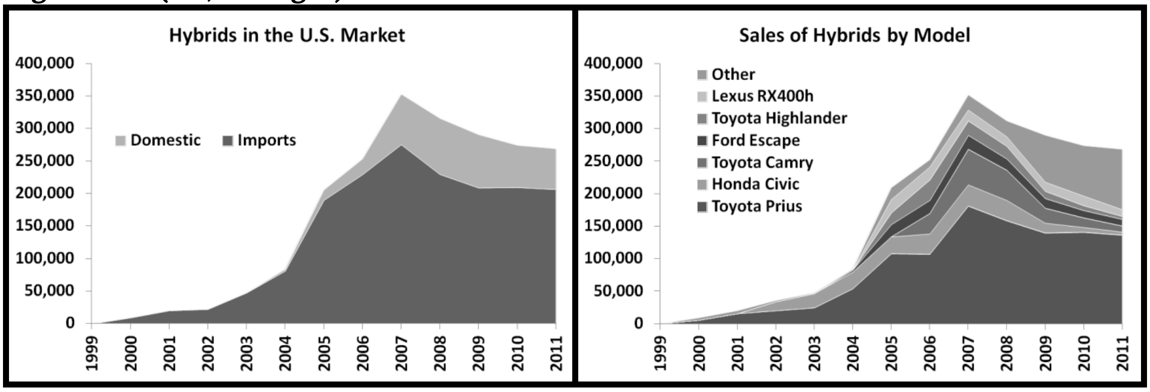
Climate change policy also experienced difficulties in California. Because of limited market demand for low-emission vehicles, CARB's fourth ZEV mandate review (1998) gave automakers more flexibility, e.g. postponing some requirements, establishing a credit system (Kemp, 2005). In 2001, CARB recognized barriers due to cost, lead-time, and technical challenges, and further amended the mandate, requiring only 2%-sales of 'pure-ZEVs' (BEVs and fuel cell vehicles) by 2003 (Kemp, 2005). CARB also gave automakers the option of meeting the remaining 8%-

requirement with 2%-sales of 'Advanced Technology Partial Zero Emission Vehicles' (AT-PZEVs), such as HEVs, plus 6% of Partial Zero Emission Vehicles (PZEVs), such as natural gas and 'super-clean' gasoline vehicles. Even so, GM (and other companies) contested the 2001 amendments in court (see below), which in 2002 resulted in a court decision, which prohibited CARB to enforce the programme (because regulating 'fuel economy' was a Federal prerogative), causing gridlock for the ZEV mandate. To overcome the political gridlock CARB's 2003 amendments removed all references to fuel economy, delayed the ZEV requirements to 2005, and included two compliance paths, one similar to the 2001 amendments (2% pure ZEVs + 2% AT-PZEVs + 6% PZEVs), the other setting up a mechanism to promote the diffusion of fuel cell vehicles: automakers would be exempted from the 2% pure ZEV requirement if they would increase sales of FCVs from 250 by 2008 to 50,000 by 2017.

Yet a positive development was that the State of California adopted the *Pavley Act* in 2002, which instructed CARB to regulate GHG emissions from motor vehicles (Sperling and Gordon, 2009). In 2004 CARB issued new rules requiring 30% reductions in new car GHG emissions by 2016 (Lutsey, 2012).

Foreign automakers. PNGV had an unintended consequence, because foreign automakers perceived it as a serious technology development program (Sperling and Gordon, 2009). In response, Toyota and Honda pushed the commercialization of HEVs, while Daimler-Benz (DaimlerChrysler from mid-1998) led fuel cell developments. The two-seater Honda *Insight* (introduced in the US market in 1999) and Toyota *Prius* (introduced in 2000) boosted the environmental and technological reputation of Japanese companies (Abeles, 2004). The Prius, in particular, became a personal statement of consumer environmental consciousness (Abeles, 2004). Hybrid sales accelerated after 2004 (Figure VII.8).

Figure VII.8 (a-b, left-right): Sales of HEVs in the US market



Source: Author's elaboration based on data from (RITA/BTS, 2012) and www.afdc.energy.gov/afdc/data/, respectively

Daimler became a leader in FCVs (Hekkert and van den Hoed, 2006). In 1999, DaimlerChrysler managed to fit a fuel-cell system (costing $35,000 apiece) on a 5-seat passenger car (NECAR 4). This led its Chairman to declare that "the race to develop the fuel cell car is over *[...]* Now we begin the race to lower the cost to the level of today's internal combustion engine. We'll do it by 2004" (quoted in The Economist, 1999, p. 88). In 2000, DaimlerChrysler announced investments of $1.4 billion to bring FCVs to market (van den Hoed, 2005). The goal was to sell 40,000 fuel cell cars by 2004, ramping up production to 100,000 by 2006 (Sperling and Gordon, 2009). These optimistic announcements triggered the 'fuel cell hype' and innovation race, with most car companies starting to engage in FCV-research (Bakker, 2010a) (see also Figures VII3.a, b and c).

In the late 1990s, most car companies therefore had a fuel cell and/or hybrid R&D programme (van den Hoed, 2007), although with different portfolio emphases (Oltra and Saint Jean, 2009; cf. Figure VII.2.d). To share the high costs of FCV development, many R&D partnerships were established, such as between DaimlerChrysler, Ford and Ballard (1997); GM and Toyota (1999) and Nissan, Renault and PSA-Citroën (2001) (Hekkert and van den Hoed, 2006). FCVs became the industry's preferred 'final' technology because of its energy efficiency, quietness, quick refuelling, and zero emissions, without compromising on performance (Sperling and Gordon, 2009). High relative costs were a problem however: hundred times higher than ICE in 1990s, at least ten times higher in the 2000s (Sperling and Gordon, 2009).

VII.4.3.2. Car industry issue responses

Socio-cultural strategies. American automakers initially endorsed the GCC approach of contesting climate science, influencing public opinion and lobbying Washington politicians (Doyle, 2000). But in the late 1990s, they changed their position because of several reasons: (a) fear that climate denial campaigns would damage their reputation in the context of increasing public concerns (Doyle, 2000); (b) foreign automakers benefitted from a 'halo effect' on their reputations for selling 'greener' cars (Abeles, 2004); and (c) they faced credibility pressures from constructive business coalitions (*Pew Center*) and the 'win-win' business discourse. Ford abandoned the GCC in 1999, acknowledging the climate change problem and calling upon the auto industry to show leadership. GM and Chrysler followed in 2000. This was a major change in position (Rothenberg and Levy, 2012), weakening the industry's front.

Political strategies. Although American automakers acknowledged the climate change problem, they politically opposed federal fuel economy standard. Also in California they testified against the ZEV mandate in CARB's 2000 hearings, arguing that consumers were not willing to pay for BEVs (Sperling and Gordon, 2009). Automakers argued in favour of the 'more promising' fuel cell technologies, and cited their voluntary research initiatives to defend that regulation was not needed (Doyle, 2000). Although CARB relaxed ZEV requirements in 2001, the industry opposed *any* kind of ZEV mandate. GM thus led a lawsuit against CARB, arguing that the ZEV-mandate was pre-empted by Federal CAFE standards (Metz, 2008). The underlying motivation was that carmakers preferred to discuss climate change regulations at the Federal level, where they had a powerful lobbying force and support of many congressmen (Sperling and Gordon, 2009).

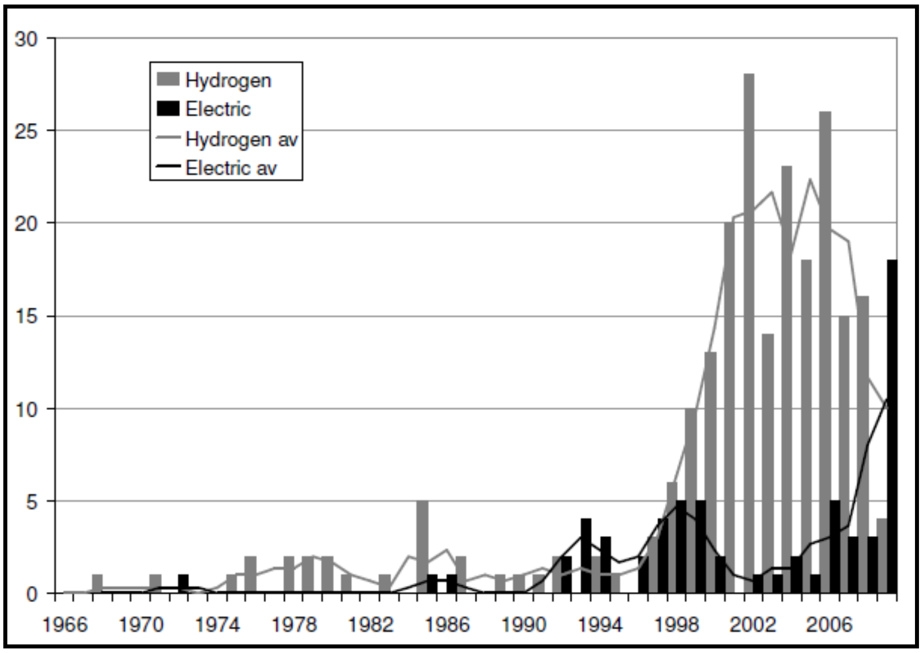
Automakers also opposed the Pavley Act (2002), suing the state of California by questioning (a) whether GHG was a pollutant under the CAA (which would allow California to set stricter emission standards) and (b) whether setting GHG emission standards was the same as setting CAFE standards (which was a Federal and not a state-level duty) (Meltz, 2007). The legal processes dragged on, gaining automakers several years of delay. Additionally, Detroit automakers secured 'political favours' from the Bush administration such as extended CAFE credits for vehicles that can burn E85, even if those vehicles never use anything but gasoline (Sperling and Gordon, 2009).

Innovation strategies. On technical dimensions, American automakers hedged. On the one hand, their main orientation remained the incremental improvement of ICEs and the marketing of flex-fuel vehicles. The combined share of aICE and FFV/biofuel patents in the Big Three annual portfolio trebled from 0.5% in 1996 to an average of 1.5% in 1997-2005 (Figure VII.3.b). On the other hand, they accelerated investments in alternative powertrain technologies, but without strong intention of mass-marketing them (Doyle, 2000).

Longer-term technology strategies shifted from battery-electric vehicles to fuel cell vehicles (van den Hoed, 2007), causing a change in industry attention (Figure VII.3.a) and industry patenting (Figure VII.3.b). American carmakers also established the *California Fuel Cell Partnership* (1999), which was a cooperative joint-venture between CARB, incumbent automakers and oil companies (Sperling and Gordon, 2009). American automakers began own fuel cell R&D initiatives. GM started a new fuel cell vehicle R&D programme in 1997 (the 'AUTOnomy Project') to develop its own fuel-cell stack technology (MacCormack, 2005). The aim was to leapfrog hybrid Japanese cars. In 1997 Ford entered in a joint-venture with Ballard Power Systems (a supplier specialized in fuel-cells) and Daimler-Benz (Budde *et al.*, 2012), but also closely followed the Japanese lead in HEVs. Ford also invested heavily in aICE and flex-fuel vehicles. Chrysler stuck to aICEs until it merged with Daimler (see below).

From 2000 to 2007, fuel cell enthusiasm resulted in increasing numbers of hydrogen/fuel cell prototypes (Figure VII.9) and optimistic promises about technological developments and commercialization). But gradually these promises were projected further (about 10-15 years) into the future, causing inflation of the hydrogen hype after 2006/7 (Bakker, 2010a).

Figure VII.9: Absolute numbers (worldwide) of hydrogen and battery-electric prototype models per year (1966-2009), with three-year moving average lines added



Source: Bakker and van Lente (2009)

In the context of the PNGV cooperation, each of the Big Three unveiled a hybrid-electric diesel prototype in 2000. But only GM's *Precept* prototype could achieve the 80-mpg goal set for 2003 (Table VII.5).

Table VII.5: Technical characteristics of the Big Three's hybrid-diesel prototypes

	GM Precept	Ford Prodigy	DaimlerChrysler ESX3
			
Equivalent fuel economy	80 mpg	72 mpg	72 mpg
Heat engine	1.3 litre, 3-cylinder diesel	1.2 litre, 4-cylinder diesel	1.5 litre, 3-cylinder diesel
Key lightweight material	Aluminium	Aluminium	Thermoplastics
Aerodynamic coefficient of drag	0.163	0.199	0.22
Weight	2,593 pounds	2,387 pounds	2,250 pounds
Battery	NiMH or Lithium polymer	NiMH	Lithium ion
Acceleration time (0-60MPH)	11.5 sec.	12.0 sec.	11.0 sec.

Source: US DoE (2005)

Critics claimed that the benefits of the PNGV were more political than technological, because it could be used by government and industry officials to claim that something was being done to address climate change (Doyle, 2000). Even the industry's trade journal *Automotive News* recognized that the Partnership 'produced few tangible results' (Stoffer, 2002). The main reason was that PNGV targeted the development of a *prototype*, not the commercialization of mass produced models (Sperling, 2002).

Market positioning strategies. The Big Three's positioning strategy continued to focus on flex-fuel vehicles, which helped them obtain CAFE credits. By 2002, flex-fuel vehicles (4.87%) made up the bulk of total AFV sales (5.18% of total US light-duty sales) (Figure VII.3.d).

Table VII.6: Alternative Fuel Vehicles available in the market by 1999

Manufacturer	*Vehicle*	*Powertrain/Range*	*Availability*
		BEV models	
General Motors	*EV1*	*Electric NiMH batteries/l60 miles*	*For lease in CA/AZ*
Toyota	*RAV4EV*	*Electric NiMH batteries/l00 miles*	*Avail to fleets*
Nissan	*AtraEV*	*Electric Li-Ion* batteries/l20 miles*	*Avail to fleets*
Honda	*EVPlus*	*Electric NiMH batteries/SO miles*	*Avail to fleets*
Solectria	*Sunrise*	*Electric NiMH batteries/350 miles*	*For sale nationwide*
Solectria	*Force*	*Electric NiMH batteries/l 00 miles*	*For sale nationwide*
General Motors	*S10 Electric*	*Electric NiMH batteries/ 100 miles*	*Avail to fleets*
Ford	*Ranger EV*	*Electric Pb-Acid batteries/60 miles*	*Avail to fleets*
Chrysler	*EPIC*	*Electric Pb-Acid batteries/50 miles*	*Avail to fleets*
Lotus	*Elise EV E*	*Electric NiMH batteries/l20 miles*	*For sale from manufacturer***
AC Propulsion	*TZero*	*Electric Pb-Acid batteries/100 miles*	*For sale from manufacturer***
Nissan	*FEV II*	*Electric Li-Ion batteries/ 120 miles*	*Demonstration*
		HEV models	
Chrysler	*Intrepid ESX*	*Hybrid gas/electric (90 mpg)*	*Demonstration*
Honda	*JVX*	*Hybrid gas/capacitor*** (70 mpg)*	*Demonstration*
Subaru	*Elten*	*Hybrid gas/electric (unknown)*	*Demonstration*
Ford	*P2000*	*Hybrid diesel/electric (60+ mpg)*	*Demonstration*
General Motors	*EV1 derivatives*	*Hybrid gas/electric (80 mpg)*	*Demonstration*
Renault	*VERT*	*Hybrid turbine/electric (unknown)*	*Demonstration*
		FCV models	
Daimler-Benz	*NECAR*	*Methanol fuel cell*	*Demonstration*
Toyota	*FCRAV4*	*Methanol fuel cell*	*Demonstration*
Chrysler	*Intrepid ESX II*	*Gasoline fuel cell*	*Demonstration*
General Motors	*EV1 derivative*	*Gasoline or methanol fuel cell*	*Demonstration*
		Natural Gas models	
Chrysler	*Voyager*	*Natural gas*	*Fleet sales*
Ford	*Crown Victoria*	*Natural gas*	*For sale nationwide*
Ford	*CNG Explorer*	*Compressed natural gas*	*Fleet sales*
General Motors	*S10 CNG*	*Compressed natural gas*	*Fleet sales*
Honda	*Civic GX*	*Natural gas*	*For sale nationwide*
		Flex-Fuel Models	
Ford	*Super Mustang*	*Ethanol/gasoline*	*For sale nationwide*
Ford	*Bifuel Taurus*	*Ethanol/gasoline*	*For sale nationwide*
General Motors	*Cavalier*	*Bifuel-natural gas/gasoline*	*For sale nationwide*
Ford	*Contour*	*Bifuel natural gas/gasoline*	*For sale nationwide*

Source: Johnson (1999) Obs.: *Li-Ion stands for lithium-ion (a variation is called lithium-polymer), a battery that by 1999 was made by Sony Corporation and 3M Corporation; **Not available from dealerships; ***"A capacitor is an energy storage device that can hold large amounts of charge between two metallic plates, allowing for nearly instantaneous release of that energy" (Johnson, 1999, p. 148).

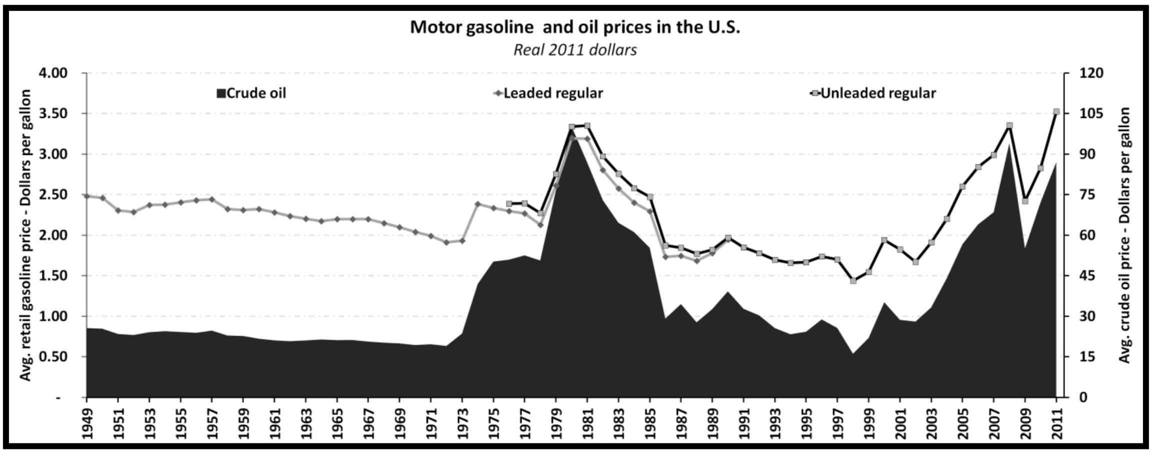
In fact, despite early BEV technology developments, by 1999, only two BEV models were available for sale (Johnson, 1999), both from outsiders (Table VII.6). In 2002, when it leased only 457 units of the second generation EV1 (which had a longer range because of lighter materials and more advanced (NiMH) batteries) (Hanssen and Spertus, 2002), GM decided to discontinue production and not to extend expiring lease contracts (Sperling and Gordon, 2009). This decision aligned with GM's political position (opposing ZEV mandate) and shifting strategy towards fuel cells (Sabatini, 2002). The decision had negative reputational effects, because critics (see e.g. the documentary *Who killed the electric car?*, launched in 2006 by a former EV1-leasee) claimed that it was a political move to obstruct the ZEV programme.

VII.4.3.3. Influences of broader industry contexts on issue life-cycle

While climate change gained salience, American automakers faced financial and competitive pressures, and their market-shares continued to decline (Figure VI.16). These pressures accelerated consolidation in the global automotive industry, with Chrysler merging with Daimler (1998), Hyundai taking over Kia (1998); Renault and Nissan establishing the Renault-Nissan Alliance (1999); Ford acquiring Volvo (1999); GM fully acquiring Saab (2000) (Orsato and Wells, 2007). American automakers became increasingly reliant on the profitable light-truck segment. To strengthen its position in this growing market (Figure VII.4), GM acquired the Hummer brand in 1998.

The oil and fuel prices increased steeply after 2003 (Figure VII.10), stimulating a shift in consumer preferences towards more fuel-efficient cars. Sales of SUVs, pick-ups, vans and wagons began to decline after 2004 (Figure VII.4), which caused financial problems for American automakers (Figure VI.17, p. 228). According to one estimate, "half of the market share decline of the Detroit carmakers between 2002 and 2007 can be attributed to the rising price of gasoline" (Klier, 2009, p. 4). To sell their cars, American carmakers offered a range of 'marketing gimmicks', such as zero-interest, rebates and free options. They also aimed to cover automotive losses with profits from financial divisions, which diversified into mortgages, including sub-prime (Ingrassia, 2010).

Figure VII.10: Motor gasoline and oil prices in the US in real 2011 dollars



Source: Based on data from the US EIA (http://www.eia.gov/petroleum/data.cfm#prices), accessed on October 23rd, 2012

VII.4.4. Changing gear and crisis (2005-2009)

This fourth period – which ends in 2009 due to the Great Financial Crisis – has some elements from phase 4 in the DILC-model: (a) sharp increase in public attention; (b) end of regulatory uncertainty (new legislation during the second Bush-administration, Supreme Court decision); (c) spillovers to the economic task environment through the emergence of market niches for low-carbon technologies; (d) further opening up of the industry front and innovation races in FCV, HEV and biofuels/FFV. Because many of these developments point in the 'right' direction, this period can be seen as one of 'changing gear' (acceleration). But the period also has elements of phase 3, because some developments are not yet very strong: (1) regulatory pressure remained limited (because federal policies are not radical); (2) market niches remained small (2-3%); (3) continuing commitment of automakers to aICE and biofuels/FFV; and (4) automakers also invested in more radical alternatives, but did not fully commit to any option for fear of making the wrong bet (which is reinforced by the experience of hype-cycles). So, overall I assess that this period is in between phase 3 and 4.

VII.4.4.1. Pressures around issue

Science, social movements, public opinion. Public attention greatly accelerated, reaching an unprecedented peak in 2007 (Figure VII.3.a), because of several catalytic events that came on top of those from the previous period: (a) the IPCC's *Fourth Assessment Report* (2007) reported a scientific consensus about an 'unequivocal warming trend'; (b) Al Gore's movie *An Inconvenient Truth* (2007) boosted climate change awareness; and (c) the IPCC and Al Gore being awarded the Nobel Peace Prize (2007). Increasing public attention created pressure on policy-makers and industry.

Policy-makers.[162] Oil and fuel prices, which had been rising steeply since 2003 (Figure VII.10), caused concerns for the re-elected (2004) Bush administration, resulting in the 2005 *Energy Act* and the *Energy Independence and Security Act* (2007). These acts signalled a shift in policy-orientation, because they were the first comprehensive energy policies in more than a decade. They also contributed to unlocking the federal regulatory stalemate. While these Acts were primarily motivated by oil prices and energy security concerns, they also stimulated low-carbon technologies in the transport domain. The 2005 Energy Act mandated a 100%-increase in the volume of ethanol mixed with gasoline between 2006-2012 (Yergin, 2011), and provided R&D subsidies for HEV, FCV and advanced battery research. The 2007 Act mandated a further increase in biofuel production to 36 billion US gallons by 2022 (Sperling and Gordon, 2009), making biofuels into a crucial national strategy (cf. Figures VII.2.b and c) and stimulating the diffusion of flex-fuel vehicles (Figure VII.3.d). The 2007 Act also raised CAFE standards for passenger cars to a minimum of 35MPG by 2020 (Figure VII.5), linking energy security and fuel efficiency to the climate change agenda.

Also in 2007, a judicial decision about the petition filed in 1999 broke the regulatory deadlock. In the 2007 case *Massachusetts v. EPA*, the Supreme Court ruled that (a) carbon dioxide and other GHGs are pollutants, and thus regulated under 1990 CAA; and (b) the CAA does not authorize EPA to make policy considerations (Meltz, 2007). This judicial order meant that existing fuel efficiency and environmental regulations could be extended to address climate change. The ruling also labelled GHGs as ‘air pollutants’, which gave CARB the right to legislate GHG emissions in California. But CARB did not yet gain the means to *implement* the legislation, because automakers successfully lobbied the Administration not to grant California the necessary waiver (Sperling and Gordon, 2009). The argument was that the 2007 Energy Act, which tightened fuel economy standards, pre-

[162] While global climate change developments (negotiations) slowed down, some initiatives tried to address automobile carbon emissions. In Europe, frustration with automakers, who were on track to miss the voluntary 1998 agreement, led policy-makers (in 2007) to issue mandatory car-emission standards for 2015 (130 gCO_2/km or 42MPG). Japan followed suit, setting its standard at 125 gCO_2/km (or 44MPG) for 2015.

empted the need for California to have its own GHG standards (Sperling and Gordon, 2009).

Foreign automakers and new entrants. BEVs were revitalized by foreign automakers such as Renault-Nissan, which in 2002 had announced a breakthrough in lithium-ion battery technology that would extend the driving range (Yergin, 2011). Renault-Nissan promised to market BEVs in 2010. A new automaker, *Tesla Motors*, further reinforced attention, because of the marketing of its *Tesla Roadster* (2006) in terms of style, verve, and performance gave BEVs a positive symbolic meaning (Yergin, 2011). The subsequent surge in interest in BEVs (Figure VII.3.a) spurred other automakers to reconsider the technology (Figures VII.3.b and c).

Another company that was founded amidst the new BEV hype promoted not a different BEV model, but a different *business* model for battery-electric vehicles: *Better Place*. Founded in 2007, this American-Israeli start-up company promoted a different kind of EV ownership, similar to mobile phone subscriptions, which includes 'switchable batteries' to tackle the limited driving range issue[163]. The company also invested in recharging infrastructures, opening the first recharging stations in Israel and Denmark. In 2008, Better Place signed a partnership with the Renault-Nissan Alliance, which planned to use the new entrant's battery-switching system (Yergin, 2011). The success of such system depends however on the emergence of a dominant design for batteries that is shared throughout the global auto industry.

VII.4.4.2. Car industry issue responses

Socio-cultural strategies. In response to escalating public concerns, automakers acknowledged climate change in their annual reports and signalled their engagement with sustainable mobility. Their sustainability reports were then marked by four 'isomorphic' themes (Shinkle and Spencer, 2012): (1) recognition of the global warming issue ('responsible' companies do not challenge its existence); (2) abide by self-defined corporate values (ethical behaviour); (3) acknowledgement of stakeholders' importance (for obtaining goodwill and legitimacy); and (4) corporate role-model responsibility (which should pre-empt the need for governmental mandates). Reflecting this new (public) approach to

[163] See http://www.betterplace.com/How-it-Works; accessed on April 15th, 2013.

societal issues, automakers sponsored the 'Sustainable Mobility' project of the *World Business Council for Sustainable Development* (WBCSD), a CEO-led organization founded on the eve of the 1992 Rio Earth Summit.[164] The final report ('Mobility 2030'), sponsored by eight OEMs (DaimlerChrysler, Ford, GM, Honda, Nissan, Renault, Toyota and Volkswagen), two oil companies and two suppliers, proposed a long-term vision for transportation of people and goods, established seven sustainable mobility goals, and created a set of indicators to measure performance (WBSD, 2004). Marketing strategies also embraced sustainability messages (Mikler, 2006).

Political strategies. Despite their positive socio-cultural strategies, the industry attempted to proactively shape policy changes with political and technological strategies. In 2007, GM, Ford and Chrysler joined the US Climate Action Partnership (USCAP), which promoted 'legislation requiring significant reductions in greenhouse gas emissions' (USCAP, 2009; Yergin, 2011). Through paid advertisements and other information strategies, the Partnership mainly called for market-based approaches and lobbied for cap-and-trade legislation (Figure VII.11).

Figure VII.11: In this 2009 advertisement, the USCAP lobbied for cap-and-trade legislation

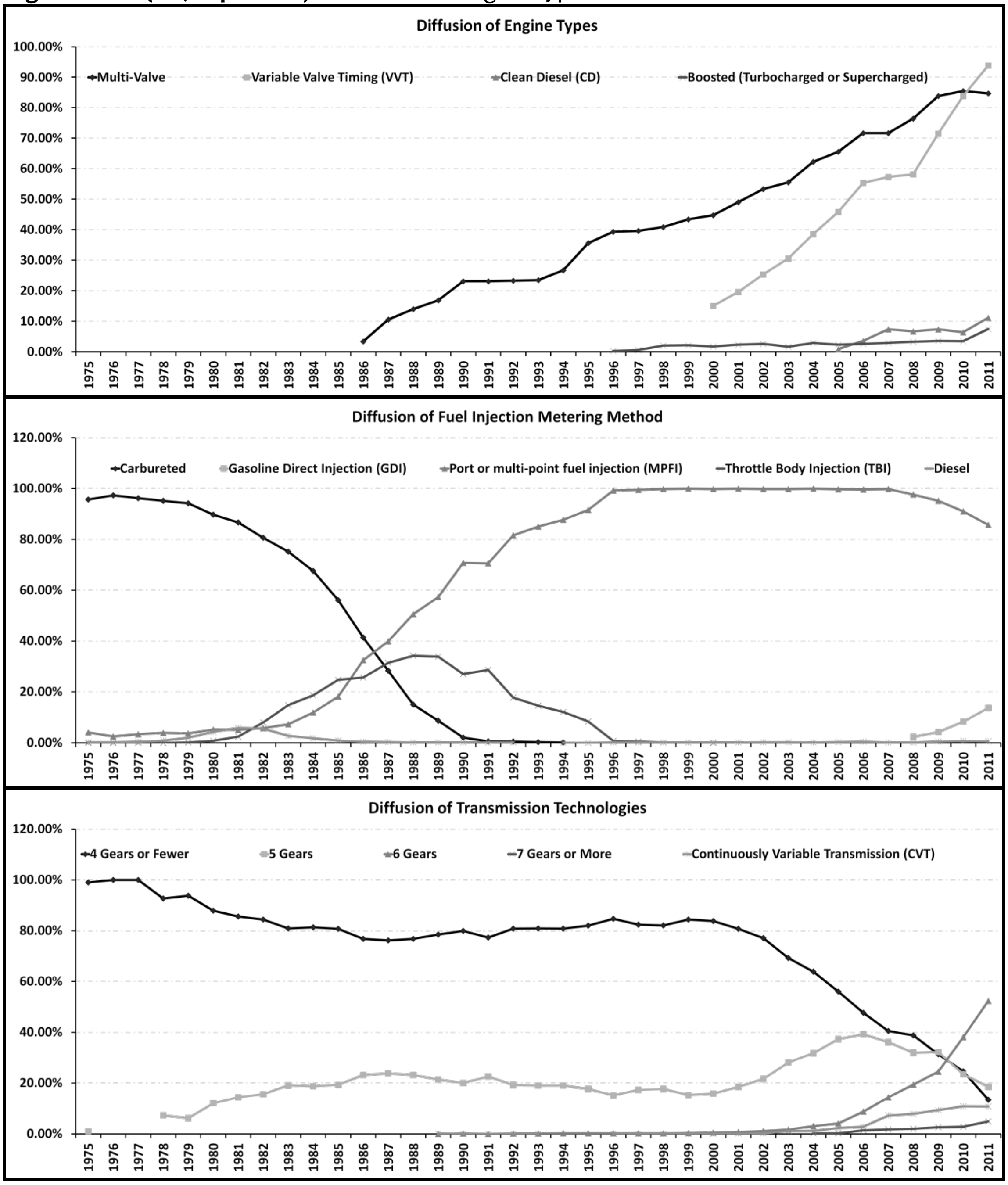
Source: http://www.us-cap.org/newsroom/; accessed on: September 25th, 2012

[164] http://www.wbcsd.org/about.aspx Accessed on September 13th, 2012.

Innovation strategies. By 2006-2007, fuel cell enthusiasm began to diminish (see Figure VII.3.a and b) because of cost problems, technological barriers (e.g. hydrogen storage), and a lack of hydrogen fuelling stations (Bakker, 2010). New expectations about HEVs, PHEVs, and BEVs superseded the fuel cell hype (Figures VII.3.a, b, c, and VII.9) (Oltra and Saint Jean, 2009; Bakker *et al.*, 2012a; Dijk *et al.*, 2013). By 2005, sales of HEVs accelerated (Figures VII.3.d and VII.8), stimulating industry attention and patenting (VII.3.a, b, c). GM, Chrysler and Ford boosted their R&D activities, leading to changes in patenting portfolio (Figure VII.3.b).

And yet, despite the EV-push, the main strategy of American automakers to improve fuel efficiency remained incremental improvement of internal combustion engines with advanced and/or flex fuel technologies. This resulted in increased shares of flex-fuel patents and aICE-related patents (Figures VII.b and d). American automakers accelerated the deployment of aICE technologies such as variable valve timing, continuously variable transmission, gasoline direct injection, turbocharging, six-speed transmission, cylinder deactivation, and diesel engines (Lutsey, 2012). Figure VII.12 shows that there is still room for improving the average fuel economy by deploying more efficient, already developed technologies to more models, such as turbo engines (Figure VII.12.a), gasoline direct injection (Figure VII.12.b), and transmissions with more gears (Figure VII.12.c).

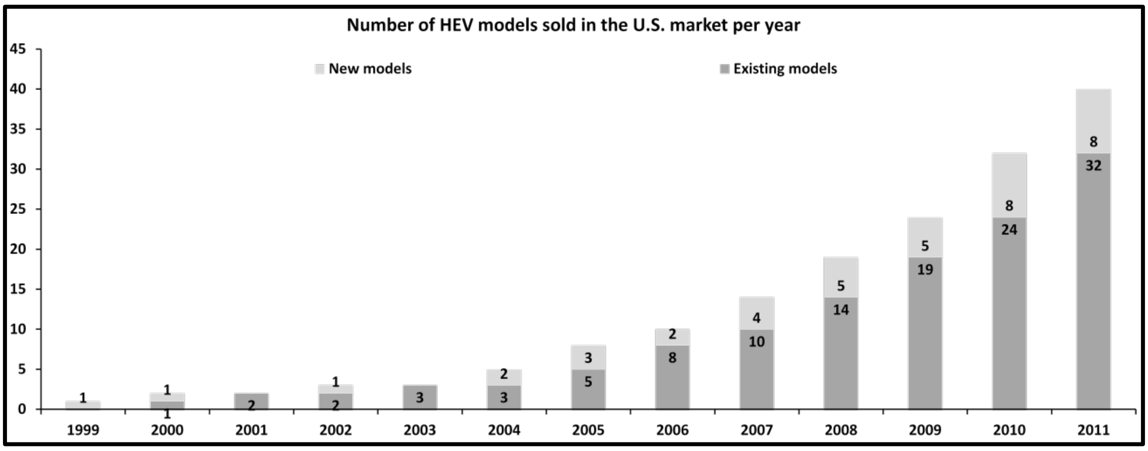
Figure VII.12 (a-c, top down): Diffusion of engine types in American cars



Source: Based on data from US EPA (2012)

Market positioning strategies. Economic positioning of American automakers continued to focus on biofuels and flex-fuel vehicles, which sold in increasing numbers (Figure VII.3.d). The HEV market, which expanded rapidly after 2005 (Figure VII.8), also attracted attention. Toyota's second-generation Prius, larger and more powerful but at similar cost ($20,000), led the way. By 2007, Prius was the 8th top selling car in the U.S (13 for all light-duty vehicles) (Sperling and Gordon, 2009). In response to Toyota's first-mover advantages, Ford produced its first full-hybrid (Escape) in 2004 (using licensed hybrid technology from Toyota) and GM, in 2007 (Sperling and Gordon, 2009). From 2005-2006, Ford sold an average of c. 18,000 Escape hybrids, which became the 4th all-time seller among HEVs models. Other companies followed, leading to an innovation race and a rapid increase in the number of available models (from 14 in 2007 to 24 in 2009; Figure VII.13). Although absolute HEV sales peaked in 2007 (Figure VII.8), it corresponded to just 2% of the US light-duty vehicle market (Figure VII.3.d).

Figure VII.13: The race for the HEV market accelerated in the mid-2000s



Source: Based on data from RITA/BTS (2012)

VII.4.4.3. Influences of broader industry contexts on issue life-cycle

General market conditions worsened, as rising oil prices continued to depress sales of light-trucks. The trend accelerated with the outbreak of the financial crisis, which depressed also car sales (Figure VII.4). American carmakers thus continued to offer the range of 'marketing gimmicks' (zero interest loans, rebates, free options). Declining light-truck sales and 'legacy' costs (pensions, health care) caused major losses for American automakers, peaking at $41.5 billion for GM in 2007 (Figure VI.17, p. 228), when the subprime bubble burst. The financial crisis caused major financial troubles for the Big Three. "Once again the Detroit Three were reaping the consequences of their lack of foresight" (Sperling and Gordon, 2009, p. 55). They now had to compete for the HEV and other 'fuel-efficient' market segments "as a matter of economic survival" (Mikler and Harrison, 2011, p. 197)

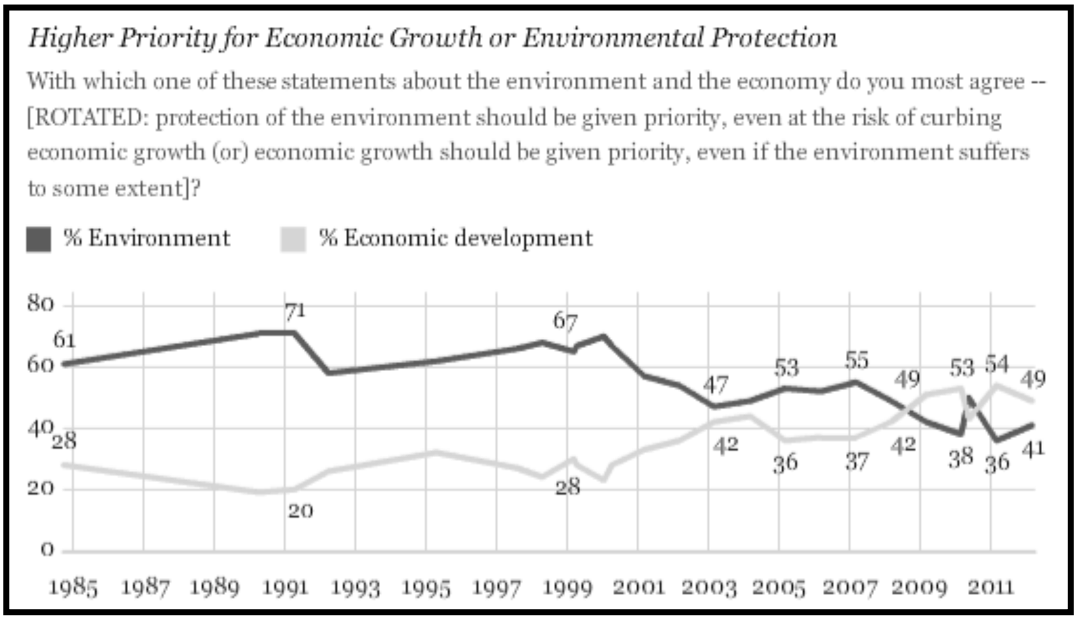
VII.4.5. The climate change issue at crossroads (2009-2012)

While most developments in the previous period pointed in the 'right' direction, the life-cycle did not accelerate in this period, with developments pointing in different directions. On the 'positive' side, this fifth period has some elements of the conceptual phase 4: (a) climate change was addressed at the macro-political level (Obama administration); (b) administrative activity remained high (Figure VII.3.c); (c) the political position of US automakers weakened (because of bankruptcy and bailout), which made them more receptive to social and political expectations about fuel efficiency and climate change; (d) automakers jockeyed for position with various low-carbon technologies, leading to high patenting activity across multiple categories (Figure VII.3.b). But the period also had 'negative' developments, which fit with phase 3: (1) decreased level of public attention (Figure VII.3.a); (2) political attention to climate change decreased after 2009 (Figure 3b); (3) new regulations are not radical and do not create a new market segment; (4) markets for HEV, BEV, PHEV remain small (2-3% of overall sales); and (5) automakers remain committed to aICE and biofuels/FFV. Although car companies continue to invest in radical green options, they do not fully commit to any of them. This period is therefore best characterized as *still* between phase 3 and 4.

VII.4.5.1. Pressures around issue

Public attention. After 2007 public attention to climate change declined substantially (Figure VII.2.a), because concerns shifted to the financial/economic crisis. In 2009, for the first time since Gallup started asking Americans about their preference in the trade-off between environmental protection and economic growth, a majority of those polled favoured the economy (Jacobe, 2012). The gap in favour of economic growth reached a record of eighteen percentage points in 2011 (Figure VII.14). A similar trend was observed with concern for global warming, which declined steadily from 2007-2011 according to another Gallup poll (Newport, 2012). While a decline in public attention is expected after the issue moves to a 'policy implementation' stage, this time the decline due to the competing economic issue would bring different implications to the process dynamics.

Figure VII.14: For the first time in 25 years, Americans favoured economic growth over environmental protection



Source: Jacobe (2012)

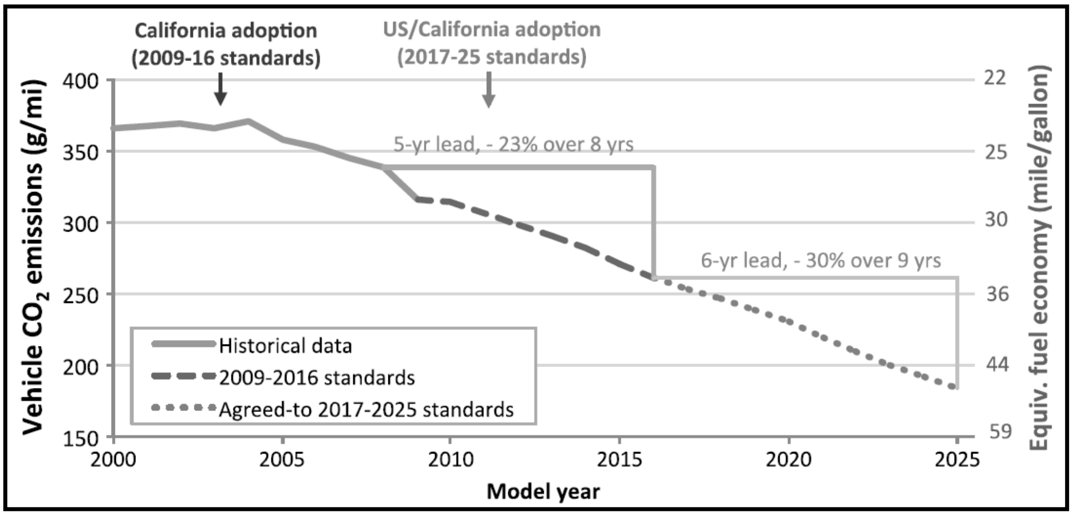
Additionally, conservative groups and thinktanks sponsored 'climate change deniers' who tried to reopen the scientific debate by manipulating evidence and intimidating scientists (McCright and Dunlap, 2010). They jumped on the 2009 'Climategate' scandal (based on leaked emails from the Climatic Research Unit at the University of East Anglia), to suggest that the IPCC manipulated data and that climate change was a hoax (Pooley, 2010). These activities contributed in creating more doubt in public opinions about climate change. The timing of this attack coincided with the preparations for the international climate change negotiations in Copenhagen (2009).

Policy-makers. International climate negotiations stalled because of failed talks in Copenhagen (2009) and a lower-profile meeting in Cancun (2010). In Durban (2011) countries agreed to delay further talks until 2015, when they will discuss a possible international treaty that could come into force in 2020. So, this period ends without a clear successor for the Kyoto protocol.

At the federal level, however, the newly elected (2008) Obama administration strengthened regulatory pressures on automakers. The administration also bailed out Chrysler and GM (in 2009), which went bankrupt during the economic crisis. Using his strengthened negotiating position, Obama secured an agreement on CAFE and GHG emission standards between auto companies, government agencies (EPA and NHTSA), and California. Subsequently, executive branch activity increased sharply (Figure VII.2.c), with EPA and NHTSA accelerating the creation and implementation of mobile GHG-emission regulations and stricter CAFE-standards.

The resulting 2009 *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards Rule* (the 'LDV Rule') created GHG emission standards for light-duty vehicles starting in 2012, which will increase 5% per year, until reaching 35.5MPG (on average) by 2016 (Figure VII.5). The rules also allowed California to start implementing the Pavley Act in 2009 (Lutsey, 2009). In 2011, the Federal government, California and automakers agreed on long-term GHG/CAFE standards (Lutsey, 2012), which should increase to 54.5MPG (on average) by 2025 (Figure VII.15). These GHG regulations remain weaker than those in Europe (and Japan), which is considering 95 gCO_2/km (c. 60MPG) for 2020.

Figure VII.15: Development of GHG emissions/CAFE standards



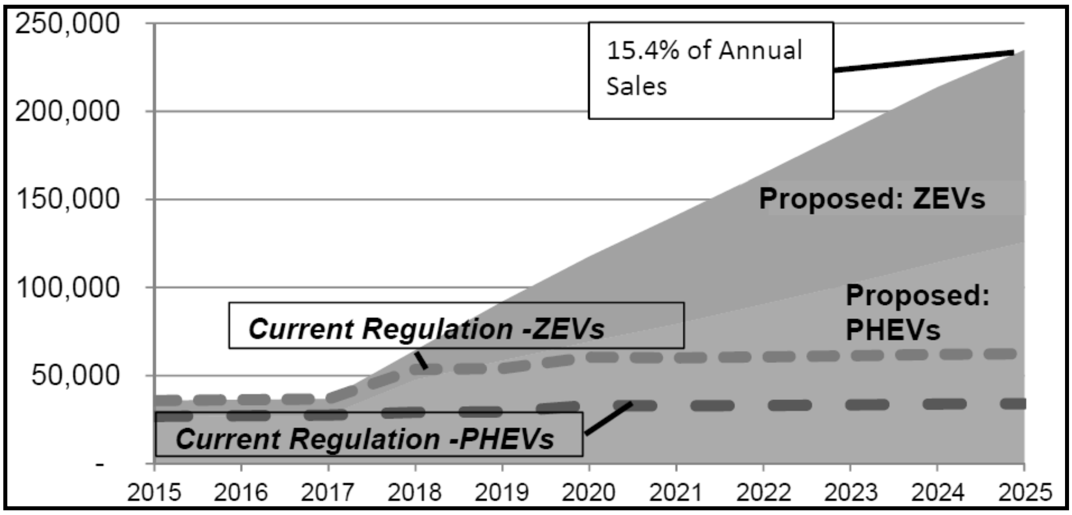
Source: Lutsey, 2012

Obama not only tightened regulations, but also supported green innovation. As part of the 'green stimulus' programme, he promoted a domestic battery industry, issuing US$5-billion in grants and loan guarantees to battery makers, entrepreneurs, major auto companies and equipment suppliers (Dijk *et al.*, 2013). Obama also promised to bring one million PHEVs and BEVs to the road by 2015, signalling a shift in federal technology priority from hydrogen/fuel cells to battery-electric vehicles (Bakker *et al.*, 2012a, 2012b).

The stalemate for the California ZEV-regulations was unlocked by the 2007 Supreme Court decision, and the 2009 Obama deal with the automakers. CARB also modified the regulations to accommodate PHEVs (and hydrogen-fuelled ICE-

FCVs). CARB created an *Enhanced AT PZEV* category (Enhanced Advanced Technology Partial Zero Emission Vehicles) and a new compliance path for 2012-2014, which allowed carmakers to sell 7,500 FCVs + c. 58,000 'Enhanced AT PZEV' instead of 25,000 FCVs. A 2012 amendment further increased requirements for ZEVs and PHEVs to 15.4% of annual sales in 2025 (CARB, 2012) (Figure VII.16). Nine other (East and West Coast) states began procedures to also adopt a ZEV-mandate.

Figure VII.16: Amendments to California's ZEV regulation



Source: CARB (2012)

Foreign automakers. Japanese automakers push for environmentally friendly products resulted in positive publicity and actual technological and corporative lead. Since the 1998MY, the Union of Concerned Scientists ranked automakers' positioning strategies for environmentally friendly products (with technological controls of both GHG and conventional pollutant emissions). Table VII.7 shows that (a) the Japanese automakers have the most environmentally-friendly fleet; and (b) the Big Three's 'green' strategies either failed or represented 'greenwashing' attempts. In all five rankings, Honda's fleet came first, while Toyota's came consistently second or third. Volkswagen also started to fare well, by deemphasizing diesel engines in the US market (Union of Concerned Scientists, 2010). On the other end of the ranking are the Big Three's gas-guzzling fleet.

Table VII.7: Automaker ranked by average new-vehicle GHG and conventional pollutants emissions

Rank	*1998MY*	*2001MY*	*2003MY*	*2005MY*	*2008MY*
1	*Honda*	*Honda*	*Honda*	*Honda*	*Honda*
2	*Toyota*	*Toyota*	*Nissan*	*Toyota*	*Toyota & Hyundai*
3	*Nissan*	*Nissan*	*Toyota*	*Hyundai*	-
4	*GM*	*Ford*	*Ford*	*Nissan*	*Volkswagen*
5	*Ford*	*GM*	*DaimlerChrysler*	*Volkswagen*	*Nissan*
6	*DaimlerChrysler*	*DaimlerChrysler*	*GM*	*Ford*	*Ford*
7	-	-	-	*GM*	*GM*
8	-	-	-	*DaimlerChrysler*	*Chrysler*

Source: Union of Concerned Scientists (2010) Obs.: Only the top six automakers were evaluated in model years 1998, 2001, and 2003.

After securing the top position as the biggest automaker in the world in 2008, Toyota faced a safety and quality scandal in 2009-10 (Allen and Sturcke, 2010): because of incidents of sudden acceleration (attributed to sticking pedals or floor mats), Toyota was forced to issue a series of recalls involving millions of vehicles worldwide. Some of these recall programmes included HEV models such as the best-seller Prius. The 'sticky Pedal Recall' caused such a public upheaval in the US, that Toyota was invited to testify before Congress. Not only the sales of the Prius declined, but also Toyota lost market-share in 2010 and 2011, losing the second place in the American market to Ford (Ward's Automotive Group, 2013).

Although positioning of FCVs continued to be a difficult undertaking, some automakers stuck to the fuel cell commitment. Honda announced in 2008 it would lease up to 200 of its *FCX Clarity* model in markets in Southern California (Milliken, 2008), in a three-year lease programme for US$600/month[165]. One year later, Daimler finally started producing a small batch of *Mercedes-Benz B-Class F-CELL* – the first fuel cell automobile in series production – leased in the US (California) and Germany beginning in 2010 (Daimler, 2012). In September 2012, Hyundai unveiled the *ix35* fuel cell model during the Paris Auto Show, and criticized other automakers for 'jumping the gun' and releasing BEVs before sufficient vehicle charging infrastructure were in place, thus hurting sale prospects. With production of the FCV model due to start in December 2012, Hyundai promised to be the first OEM to mass-produce FCVs by 2015 (King, 2012).

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[165] http://automobiles.honda.com/fcx-clarity/; accessed on October 3rd, 2012.

VII.4.5.2. Car industry responses

Socio-cultural strategies. To increase the chances of Federal bailouts, American automakers tried to enhance their social and political legitimacy by subscribing to environmental and fuel economy expectations. GM's first Viability Plan (December 2008), for instance, claimed that: "General Motors well understands the challenges to energy security and the climate (...) and believes that (...) we must look to advanced vehicle technologies to reduce petroleum dependency and greenhouse gas emissions" (p. 4). With the surging interest in electric vehicles, automakers also showcased PHEV and BEV concept-cars such as the *Chevy Volt*. The first Viability Plan therefore included ambitious investment plans in green technologies (Table VII.8).

Table VII.8: Investment plans in GMs first Viability Plan (2008)

Technology	*Fuel economy improvement impact*	*2009-2012 Investment*
Hybrid (BAS+)	*12-15%*	*$467 M*
Strong hybrid (large vehicle)	*30-35%*	*$515 M*
Strong hybrid (small vehicle)	*35-55%*	*$315 M*
Extended range electric vehicle (e.g. Volt)	*100-120%*	*£758 M*

Source: GM (2008)

The Viability Plan was reviewed by the *Presidential Task Force on the Auto Industry* (ATF), which Obama created for fear of being accused of interfering with day-to-day management. The Auto Task Force rejected the focus on green cars, because of limited financial prospects.[166] GM's second Viability Plan (2009) therefore paid less attention to green innovation and did not include green resource allocations (Rattner, 2010).

Political strategies. Because Detroit automakers needed Federal funds for survival, they became more cooperative towards environmental regulations and signed up to various substantial CARB and CAFE agreements. By 2012, however, they resumed defensive political strategies, arguing and lobbying against the ZEV-mandate. An industry petition to EPA against California's regulation argued that:

> *It is impossible to predict today whether infrastructural developments, oil prices, consumer confidence and other factors will converge such that*

[166] In his memoirs, ATF's director notes that: "We discussed the prospects of the Volt, and it quickly became clear that the car had commercial clay feet. (...) The bottom line was that there was no way for the Volt or any next-generation car to have a positive impact on GM's finances any time soon" (Rattner, 2010, p. 97).

> *automakers will be able to persuade buyers to* [buy sufficient numbers of electric-drive cars]. *Current data and trends suggest that it is highly unlikely that the industry will be able to meet that mandate.* (Quoted in Automotive News, March 12th, 2012).

Automakers also opposed the Californian ZEV-mandate in an attempt to discourage nine other states from adopting it.

Innovation strategies. Before the crisis, Ford and GM displayed BEV and PHEV-prototypes (*Chevy Volt*, *Ford Airstream*). GM even announced production plans for the Volt, signalling a shift in strategy from fuel cells to BEVs. The financial crisis created delays, because the Auto Task Force was unenthusiastic about the Volt. But in 2010 the first Volt rolled off the factory production lines.

Following the (re)established Californian ZEV-regulations, automakers announced BEV commercialization plans to meet required sale-quotas. The *Green Car Reports* (a consumer-support website for green cars) qualified many models (Chevrolet Spark EV, Ford Focus Electric, Honda Fit EV, Toyota RAV4 EV, and the Fiat 500e) as 'compliance cars', which are "not meant to lure in consumers, or sell in any kind of volume. They're *only* built to meet California regulations for zero-emission vehicles" (published on 3/5/2012). These models, which are conversions of existing gasoline vehicles rather than purposively-built BEVs, are sold below cost-price.

Despite the BEV-push, advanced-ICE (and flex-fuel) technologies remained automakers' preferred strategy to improve fuel efficiency (Lutsey, 2012), leading to accelerated deployment of aICE technologies such as variable valve timing, continuously variable transmission, gasoline direct injection, turbocharging, six-speed transmission, cylinder deactivation, and diesel engines (Figure VII.12).

Market positioning strategies. The 2009 *Car Allowance Rebate System* (CARS), commonly known as the 'Cash for Clunkers' scheme, positively affected demand for more fuel-efficient cars. The US$3-billion car scrappage program offered consumers a credit of US$3,500-US$4,500 toward the purchase of a new, more fuel-efficient vehicle (Pugh, 2010; Klier and Rubenstein, 2012). By the end of the programme, almost 700,000 cars had been traded in, with Toyota emerging as the biggest 'winner', accounting for 19.4% of sales (Table VII.9). In the top-ten list of models bought, only two were not from Asian OEMs, while *all models* in the top ten models scrapped were from the Big Three (Table VII.9). The CARS scheme helped HEVs reach a peak in relative sales in 2009 (Figure VII.3.e), but the segment market-share declined thereafter, with the niche apparently saturated. Moreover, Cash for Clunkers also encouraged the diffusion of more fuel efficient ICE-vehicles (Dijk *et al.*, 2013).

Table VII.9: Official US DoT ranking at the end of the 'cash for clunkers' programme

Rank	*Top trade-in models*	*Top new models*	*Top new-model manufacturers*	
1	*Ford Explorer 4WD*	*Toyota Corolla*	*Toyota*	*19.4%*
2	*Ford F150 Pickup 2WD*	*Honda Civic*	*General Motors*	*17.6%*
3	*Jeep Grand Cherokee 4WD*	*Toyota Camry*	*Ford*	*14.4%*
4	*Ford Explorer 2WD*	*Ford Focus FWD*	*Honda*	*13.0%*
5	*Dodge Caravan/Grand Caravan 2WD*	*Hyundai Elantra*	*Nissan*	*8.7%*
6	*Jeep Cherokee 4WD*	*Nissan Versa*	*Hyundai*	*7.2%*
7	*Chevrolet Blazer 4WD*	*Toyota Prius*	*Chrysler*	*6.6%*
8	*Chevrolet C1500 Pickup 2WD*	*Honda Accord*	*Kia*	*4.3%*
9	*Ford F150 Pickup 4WD*	*Honda Fit*	*Subaru*	*2.5%*
10	*Ford Windstar FWD Van*	*Ford Escape FWD*	*Others*	*6.2%*

Source: USDOT (2009)

While the HEV niche segment seemed saturated, automakers started to position PHEVs and BEVs in the US market. GM sold a limited number of Chevy Volt's in 2010 for c. US$33,500 (GCC, 2010), including the new $7,500 tax credit from the Federal government for PHEVs with such a range, but excluding state credits. The Volt competed directly with the Nissan *Leaf* (Yergin, 2011), a BEV model also launched in 2010 for c. US$25,300, including the same incentives as the volt (Bristow, 2010). Despite incentives, prices were still too high compared to conventional models, and sales of BEVs remained low (Table VII.10). Toyota also started selling its PHEV version of the third generation Prius in 2012, but it only qualified to a US$2,500 Federal incentive, due to its limited battery range, and thus cost c. US$30,000 (Blanco, 2011). Sales of the Prius PHEV were less than half those of the Volt. Besides Tesla's models, other four PHEV/BEV models were on sale in the US by September 2012: Toyota *RAV4 EV*, Mitsubishi *i-MiEV*, Honda *Fit EV* and *Smart Fortwo EV*.[167]

[167] http://hybridcars.com/market-dashboard.html; accessed on October 4th, 2012

Table VII.10: *Sales in the US market of selected PHEV and BEV models*

	2010	2011	2012	Total
Chevy Volt (PHEV)	326	7,671	23,461	31,458
Toyota Prius PHEV	-	-	12,750	19,512
Nissan Leaf (BEV)	19	9,674	9,819	12,750

Sources: HybridCar.com; Voelcker (2012)

VII.4.5.3. Influences of broader industry contexts on issue life-cycle

Because of the economic crisis, general market conditions worsened dramatically. Plummeting sales (Figure VII.4) caused major financial problems for Chrysler and GM (Figure VI.17, p. 228). The government rescued both companies with a managed bankruptcy (2009) and substantial bailout (US$8 billion and US$30 billion loans to Chrysler and GM respectively), with Chrysler being later acquired by Fiat. All Detroit automakers subsequently restructured (shutting down factories, reducing staff, disinvesting brands), cut costs and returned to profitability (Pugh, 2010; Klier and Rubenstein, 2012).

VII.5. ANALYSIS

VII.5.1. Pattern matching with phases in the DILC-model

While the case study showed good fit with the DILC-model, the empirical periods in the case study were, as expected, more complex than the conceptual phases, with e.g. some periods containing elements from multiple phases. Indeed, there were two important deviations between the case and the phase model: (1) the industry front opened up earlier than predicted (in the third rather than fourth period). This early 'opening up' was related to radical innovations (FCV and HEV) promoted by foreign companies, which triggered responses from American automakers; and (2) lack of a single technological solution to which automakers could reorient in later phases of the DILC-model. Both deviations relate to the theoretical goal of the case study (investigating technology hype-cycles), and thus were somehow expected. I will elaborate on the implications for the DILC-model in the next section.

If deviations can be explained with the aid of the model's conceptualization, then its internal validity remains. This seems to be the case. The case showed deviations in each period, because: (a) public attention experienced significant ups and downs (signalling varying degrees of public concern with the issues); (b) multi-level policy developments at the state, federal and global level experienced advances and deadlocks; (c) conservative, climate-change denying organisations attempted to reopen the science; and (d) influences from wider industry contexts and other issues (such as safety and energy security).

Despite the complexities and deviations, which I noted at the start of each period, I try to identify an underlying pattern using the DILC-model as heuristic. The empirical goal of this case study, stated in the introduction to the Chapter, was to assess at which stage is the American auto industry climate change issue life-cycle. As in the other case studies, I do not expect a perfect match between the ideal-type DILC-model and this complex case. Yet, for the 33-year period, the model allows me to identify an overall pattern, in which the climate change issue life-cycle progressed through the following phase-sequence: 1 – 2 – 3 –3½ – 3½. This suggests that the fourth and fifth period were stuck between phase 3 and 4, which is the most difficult transition in the DILC-model (entailing radical policies, substantial market demand, and industry reorientation). Especially in the fifth period, developments point in different directions, which may prolong uncertainties and hedging strategies.

For the years until the mid-term review of CAFE rules in 2018, I suggest the following theory-informed assessment, using concepts from the DILC-model:

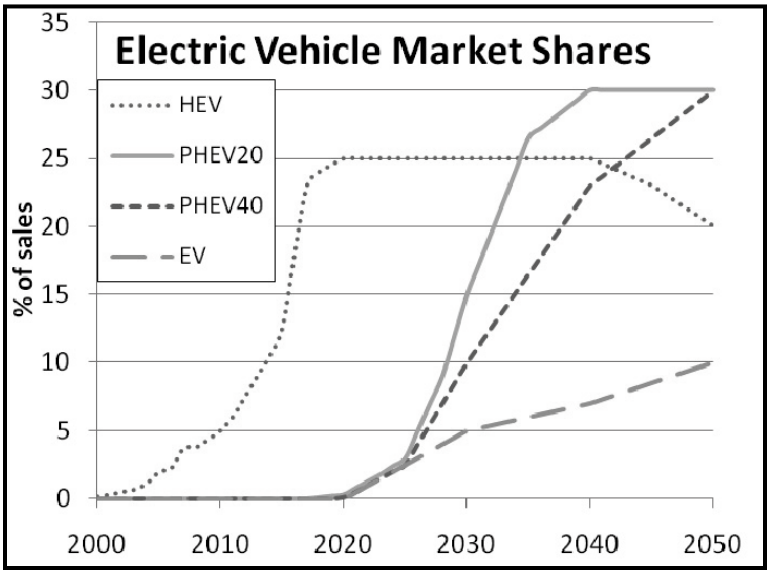
- *Policy*: Current CAFE standards are not yet tough enough to accelerate radical green innovations. While policy-implementation activity is currently high (Figure 3b), Congressional attention has decreased since 2009, which suggests that the political appetite for tough legislation may be limited in the coming years.
- *Policies and public opinion*. Strong public concerns are needed to create support for radical policies, which might facilitate a shift towards phase 4 in the DILC-model. But public attention for climate change has been declining since 2007 (Figure VII.2.a). Increase in public concern with climate change will need to return to spur a transition to phase 4. This is unlikely if the American economy fails to return to a substantive growth path.
- *Industry political strategy.* The industry has a track-record of successfully obstructing or delaying policies. Politically, I expect industry actors to continue opposing ZEV-mandates and any proposals for tougher regulations, because

these threaten current investments in aICE to comply with recent CAFE standards (cf. Lutsey, 2012).

- *Industry innovation strategy.* In terms of technical implementation, automakers are therefore likely to continue on the path of biofuels/FFV and incrementally improving ICEs, which enables them to meet CAFE standards.[168] I do not expect major industry commitment to radical green options in the next few years, because of high risks and costs, low market demand (see below), and because of limited policy pressure. Instead, I expect automakers to continue to hedge and develop capabilities in multiple low-carbon technologies (as visible in their patenting portfolio, Figure VII.3.b). This diversity shows, firstly, that automakers *are* preparing for low-carbon futures, but, secondly, that they remain uncertain about the best long-term option (which delays full commitment as I argued above).
- *Market demand*: Sales of electric-drive vehicles (EDV) declined since 2008, but expanded again in 2012 (Figure VII.3.e). Demand is still relatively small, however, providing insufficient incentive for automakers to take the risk of aggressively developing and marketing electric vehicles. Projections of future sales are uncertain, but even in optimistic scenarios electric-drive markets remain relatively small. In 2009, a positive scenario by DoE (Figure VII.17) predicted that HEVs might achieve 25% market-share by the end of the decade, when the stringency of regulations will be ratcheted up (Lutsey, 2012), and that PHEVs might achieve 10% market share by 2030, and BEVs about 5% (Figure VII.17). These estimates may be rather optimistic. HEV market shares, for instance, hovered between 2-3% since 2007 instead of increasing to 6% by 2012 as in DOE's scenario. If market demand for electric cars remains relatively low, the industry may call for a rollback of long-term standards during the mid-term review (2018) of CAFE rules (which it did successfully during the 1998 review of the ZEV mandate).

[168] "This is a strategy of least-compliance, to meet the regulatory requirements at as low a level of compliance as the regulation allows and with the lowest possible risk to the business" (Wells and Nieuwenhuis, 2012, p. 1685).

Figure VII.17: US DOE Multi-Path Study's Optimistic Scenario of EV Market Shares



Source: Gaines and Nelson (2009)

- *New entrants*. Dynamics may speed up (towards phase 4) if new entrants dedicated to electric drive are successful. *Tesla Motors*, for instance, might drive down production costs and enter larger markets (as it plans); Tesla has recently announced its first quarterly profits in the 1Q2013. Although new entrants[169] could break the mould of the American automobile industry, they have to compete against powerful incumbents locked into ICE technology, which is still supported by policies, market demand and public opinion.

Until 2018, I therefore expect the climate change issue life-cycle to remain stuck in 'phase 3½' or even cycle back to phase 3: electric drive market share may build up slowly, but not yet stimulate automakers to fully reorient towards a single solution; and in the absence of public support, there will not be political will to strengthen regulations and there could even be regulatory rollbacks.

VII.5.2. Explanation-building based on the DILC-model

VII.5.2.1. Technology hype-cycles

The co-existence of multiple solutions and technology hype-cycles adds complexity to the issue life-cycle, because they increased uncertainties and risks. Firms are

[169] Other new entrants developing electric vehicles are *BetterPlace*, *Fisker Automotive* (from California) and *BYD Auto* (from China). All three are facing financial troubles. The first filed for bankruptcy in Israel in May 2013. Fisker Automotive stopped production in Summer 2012 and is seeking new investors (its battery supplier, A123 Systems went bankrupt). *BYD Auto* could be a game changer, due to the size of the Chinese market (which could help drive drown mass-production costs), and because it may benefit from substantial state support. Yet, BYD reported a 98% plunge in profits in 2012 and has postponed sales of its all-electric minivan in the US market.

reluctant to fully commit to radical green options, because "moving from the lab to the marketplace is hugely expensive and very risky" (Sperling and Gordon, 2009, p. 77). Committing to the 'wrong' technology can have major implications, possibly even bankruptcy. So, diversity of green options, and awareness of previous hype-disappointment cycles, may delay full industry commitment.

The original formulation of the DILC-model implicitly assumes that the technical solution becomes increasingly clear as the issue progresses, so that, by phase 4, there is a single, clear-cut option towards which firms can reorient. This did not (yet) happen in the case study, which instead showed successive technology hype-cycles. I therefore advance the following proposition, which elaborates an implicit assumption in the DILC-model: the shift from phase three to phase four requires the convergence of industry actors (and other stakeholders) towards a dominant solution.[170] The absence of convergence helps explain why the fourth and fifth empirical period still had elements of phase three.

In Chapter VI, I suggested that four factors may prevent issue life-cycles from 'closing down' (possibly leading to cyclical path in which issues move backwards and forwards through phases): (1) changing interpretations and framing of the issue; (2) changes in the orientation and relative strength of issue-proponents and issue-opponents; (3) influence from other issues; and (4) changes in wider industry contexts. Technology hype-cycles relate to factors (1) and (2) because they represent changes in interpretations of solutions and changes in the orientation of industry actors, policy-makers and, potentially, consumers. These factors provide deeper explanations of why ongoing hype-cycles complicate the shift from phase three to phase four in the DILC-model.

VII.5.2.2. Regime reorientation towards 'green' vehicles

During the case study period, some changes have occurred in elements of the industry regime. Firstly, the industry has developed competencies in radically new technologies (fuel cells, electric drive). But automakers are not yet fully committed to them, and also have elaborated existing competencies via advanced ICE and biofuels/FFV. The innovation races and hype-cycles from the late 1990s (FCV, HEV,

[170] The convergence of industry actors also actively contributes to *making* a solution dominant. But firms are not the only relevant actors in creating a dominant design. Other actors (e.g. consumers, policy-makers) also make contributions.

BEV) did begin to undermine the ICE dominance. But to avoid risks, manufacturers used "a gradual, contained experimentation [of alternative vehicle technologies], as much as possible anchored within the status quo" (Wells and Nieuwenhuis, 2012, p. 1686).

Secondly, beliefs have only marginally changed: the industry no longer denies the existence of climate change and perceives it as a relevant issue. But climate change has not (yet) entered the core 'mindset' or become part of the industry's identity or mission (despite advertisements). Thirdly, climate change has entered industry-specific policies, initially via technology development programs (USABC, PNGV, Hydrogen Fuel initiative), and recently also via CAFE and fuel economy regulations. While these regulations create some pressure on the industry, they are not (yet) very tough to substantive alter the regime.

So, the changes in industry regime elements are not yet very substantial. This seems in line with the DILC-model, which suggests that major regime change does not happen until phase 4 or 5. I expect limited regime change until the issue life-cycle moves to phase 4.

VII.6. CONCLUDING REMARKS

VII.6.1. Evaluation of the mixed-methods approach

I believe that the novel methodology that I proposed showed its full potential in this case study, being particularly suitable to link theory (the DILC-model) and empirical analysis. The visual examination and the quantitative structural-break analysis helped to systematically identify periods, which were used for a meta-analysis of correlations. The visual examination and the correlation analysis also provided initial insights (patterns and relationships) into issue life-cycle and issue attention-cycle dynamics. The sub-periods could then be used in the in-depth qualitative case study narrative, which also further investigated deeper mechanisms behind the initial insights.

The quantification approaches did however present limitations, related to the length of the time-series that I used. Because sub-periods represented small sample sizes, the power of the statistical tests was low. I suggest that this issue can be overcome through the use of quarterly, monthly or even daily datasets, which however may require programming skills to automatically collect data from online database.

VII.6.2. Implications for thesis' research focus and questions

The case study has shown the usefulness (versatility) of the DILC-model for comprehensive analyses of societal problems and industry reorientation in a contemporary setting. It also brought about important insights to further elaborate the model, the most important of which, discussed above, relates to technology hype-cycles.

As a second elaboration I propose is to nuance the implicit sequential view of technological reorientation in the DILC-model (incremental innovation, hedging, diversification, full reorientation). Whereas the DILC-model assumes that incumbent firms do not engage in radical innovation until phase 3, the case study showed that automakers already developed and publicly displayed BEVs in the second period, followed by FCV, HEV, and PHEV in later periods. So, rather than a sequential process, radical and incremental innovation co-existed simultaneously from early periods.[171]

To explain this deviation, I problematize the distinction between symbolic and substantive action (Chapter II), particularly the idea that technology (only) represents substantive action in the economic task environment. I propose that technology can also be used for political and socio-cultural reasons towards the institutional environment, as indeed raised in the review chapter. The case study entailed several examples of this:

- In 1990 GM showcased the *Impact* for reputational reasons (showing it was still an innovative company). The unintended consequence was that it triggered an early BEV-related innovation race, because CARB interpreted the car as indicating that BEVs were market-ready, which led it to introduce the tough ZEV-mandate.
- The industry established public private partnerships (USABC, PNGV) to develop new technologies. Although these PPPs carried costs, they also offered the industry political and reputational benefits: control of technology developments, control over information provision to policy-makers, limiting

[171] This does not mean that the industry was equally committed to both. The case study clearly showed that the industry remained overwhelmingly committed to existing ICE competencies in all periods.

internal competition, enhancing public reputation, signalling that self-regulation was better than formal regulation, signalling willingness to take substantive action, managing technical expectations (e.g. promising major technical breakthroughs 5-10 years in the future).

- Toyota improved its green credentials with the Prius, creating an environmental 'halo effect'.
- The industry shaped social and political expectations by parading concept cars and prototypes and making promises about marketing plans. For example, the ZEV regulation 'forced' technologies as much as technologies 'forced' modifications to it. The industry has however a track-record of missing these promises, and deferring new promises further into the future (which aim to delay actual implementation).

These examples indicate that symbolic reasons are important for the (early) engagement of incumbents with radical innovation. So, the elaboration of the DILC-model is to acknowledge, firstly, that technology strategies may be pursued for substantive *and* symbolic reasons and, secondly, that early engagement with radical innovation tends to be motivated primarily by symbolic reasons. This insight represents important clue to answer this thesis' third research question ('when and why do industry actors decide to develop substantive technological responses?').

VIII. DISCUSSION AND CONCLUSION

VIII.1. INTRODUCTION

In this thesis, I aimed to contribute to the debate concerning how incumbent firms may be stimulated to help to address 'Grand Societal Challenges' (or societal issues in general). This constitutes a new and important topic in innovation studies and associated policy agendas. In so doing, I have attempted to address a gap left under-addressed for many decades in science, technology and innovation (STI) studies, where the connection between technological developments and broader societal issues remained under-theorized.

To guide my theory building and research effort, I have raised and sought to answer the following research questions:

A) How do societal issue-related pressures (on industries), from different domains (namely, civil society, science, political arena, economy), evolve?
B) How do industries respond to changing pressures around societal issues, in terms of technological, political, cultural and economic strategies?
C) In particular, when and why do industry actors decide to develop substantive technological responses?

As a first approach to answering these questions, I have developed a new framework – the *Dialectic Issue Life-Cycle* (DILC) model – that combines insights from existing theories to explain how societal issues and industry response strategies co-evolve over time. The model was inspired by insights from the Greening of Industry literature (reviewed in the introductory Chapter I): namely, that societal problems and industry response strategies progress in *stages*, representing a longitudinal, multi-dimensional co-evolutionary process at the organizational-field level. I thus used a field-level background framework of industry dynamics (the 'Triple Embeddedness Framework') to develop the DILC-model, which is based on issue life-cycle theory (reviewed in Chapter II). My review showed that this theory, from the Business & Society field, had some theoretical and methodological under-conceptualizations (gaps) about: (a) the processes through which an industry shifts to substantive responses (e.g. technological strategy); (b) the interplays between firm-level and collective (industry-level) strategies; (c) the relationship between an issue life-cycle and issue *attention*-cycles; and (d) the criteria for the conceptual and empirical identification of issue life-cycle stages. In order to address these gaps, I discussed insights from Science, Technology & Innovation (STI) studies; from Organizational Institutionalism works on corporate political activities and inter-organizational relationships, and from issue attention-cycle theory and studies on technology hype-cycles.

In Chapter III, I mobilized the reviewed literature to develop the DILC-model, which both provides a conceptual answer to my research questions and represents an analytical framework through which more nuanced answers can be derived (based on findings from empirical cases). In Chapter IV, I discussed ontological, epistemological and methodological issues that guided the application of the model to empirical cases, which were selected according to conceptual (and practical) criteria. In subsequent chapters (V-VII), I proceeded to empirically explore the framework with the aid of a novel mixed-methods approach, by studying the responses of the American automobile industry to three different societal issues (local air pollution, car safety and climate change). Each empirical chapter ended with a pattern-matching analysis, an explanation building exercise that looked at individual case idiosyncrasies, an evaluation of the quantitative methods, and implications to the thesis' research focus and questions.

This concluding chapter will now answer the research questions and compare them with the three empirical case studies. In section VIII.2, I will explicitly elaborate the conceptual answers based on the DILC-model, and then discuss how the empirical evidence match or not these answers (i.e. to what degree do the cases match the DILC-model conceptualization?). I will show that the cases had a relatively good match with the model, but all presented deviations, some of which are significant and can be used to nuance the answers and refine the model. Thus, in section VIII.3, I will advance nuances and refinements to my conceptual answers and model, based on these deviations and also on key findings of the case studies.

As this thesis employed a novel mixed-methods (quantitative-qualitative) methodology, section VIII.4 discusses and evaluates it, which, I argue, represents an original methodological contribution. Then, in section VIII.5, I make explicit this and other original claims to knowledge that I have made in this thesis. In the final section VIII.6, I will make a reflection on these contributions, by recognizing the limitations of my research and model, qualifying the generalizability of my findings and conclusions, and identifying areas for future research.

VIII.2. ANSWERING THE RESEARCH QUESTIONS

Before I present the answers to my research questions, I will explain how I will proceed in my analysis of matches and mismatches between empirical cases and conceptual model. For questions A and B, matches and mismatches can be assessed on two levels: (1) whether every *empirical period*, in which I divided each case's overall issue life-cycle, matches or not any of the five *conceptual phases* of the DILC-model[172]; and (2) whether sequence of phases that result from this first pattern-matching analysis matches or deviates from the 'normal' sequence of phases (1 – 2 – 3 – 4 – 5). In the case of research question C, the pattern-matching exercise is a consequence of point (1): my conceptual answer to the third research question explains when – in which stage of the DILC-model – the industry begins to shift from symbolic to substantive (technology) strategies, and why, i.e. which are the causes for the shift. Here, a 'good match' means that the empirical case confirmed this conceptual pattern and the proposed causal mechanisms.

Regarding point (1), a perfect match is very unlikely due to empirical complexities and contingencies, so that a 'good match' happen if key underlying processes of a given conceptual phase can be identified in the empirical period, even in the presence of deviations. The DILC-model will present *internal validity*, if deviations can be explained by the mechanisms posited in the model. Yet, even if they can be explained by the model's mechanisms, some empirical deviations may warrant nuancing the answer and refining the conceptual model (e.g. if they recurred in the cases or if they indicate the existence of different processes and mechanisms at work in an issue life-cycle), which I will do in the section VIII.3.

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[172] Throughout this Chapter, whenever I use 'period(s)', I am referring to the 'empirical period(s)' of the case studies; whenever I use 'phase(s)', I am referring to the 'conceptual phases' of the DILC-model.

VIII.2.1.Research question A

How do societal issue-related pressures (on industries), from different domains (namely, civil society, science, political arena, economy), evolve?

Conceptual answer. In the DILC-model, societal issue-related pressures evolve in phases/stages. They first emerge in civil society through the actions of activists (phase 1) and, later (phase 2), social movement organizations, both of whom engage in attention advocacy (attempts to draw attention from other actors to the issue), promoting a particular framing to the issue that poses a threat to the industry. This process results in a shared sense of urgency (possibly influenced by new scientific understandings) that is reflected in increasing public attention to the issue, which spills over to the political arena, where, in phase 3, policy-makers engage in heated debates on the problem and propose solutions. The growing visibility of the issue in this phase also attracts attention from industry outsiders, as an initial demand from concerned consumers means the issue spilled over to the economic environment. The highest visibility of the process happens when macro-politicians (e.g. the president, other political leaders) get involved: this is the turning point in the evolution of societal issues, between phases 3 and 4. More substantive pressures from the economic environment happen (either) through the implementation of strong regulation (one capable to force innovation into markets) and (or) through competitive struggles in the task environment for a growing market niche (phase 4), both of which influence mass consumer preferences (which also change with the institutionalization of the issue) (phase 5).

Discussion of match and mismatch between empirical cases and conceptual pattern. In terms of how issue-related pressure evolves, the case studies seem to confirm the underlying processes conceptualized by the DILC-model, because each period of the three cases could be characterized as a conceptual phase. Yet, periods also showed deviations, some of which warrant nuancing the answer and refining the model. In the following analysis[173], for each case study I will first discuss the matches and show which sequence of phases each empirical case followed. Then I will discuss the deviations in each case, indicating which ones seem to warrant nuancing the answers and/or refining the model.

[173] The same will be done in discussing the conceptual answer to research question B.

- <u>Local air pollution and the American automobile industry (case study 1):</u> In the first period pressure came from civil society (concerned citizens and media), as in the model's phase 1. The second period matched phase 2 dynamics: it started when new social movement organizations enacted pressure and engaged in attention advocacy, leading to minor spillovers to public opinion. The third period was close to the predicted pattern (phase 3) in the sense that the issue spilled over to the policy domain when public opinion became more concerned (i.e. public attention increased considerably). So, the third period was of political debate, but also entailed initial regulations (early emission standards), which is a deviation (see below) connected to multi-level governance dynamics (i.e. developments in California). While the fourth period matched the model's phase 4, in the sense that strict regulations were introduced (1970 Clean Air Act – CAA), it also deviated, as there was no visible demand for low emission cars (see below). The enactment of the CAA was followed by a decrease in public attention to the issue, so that it represented a turning point in the process. The fifth period was however still close to phase 4, because policy and public opinion pressure weakened, but not due to the factors suggested in the DILC-model's phase 5 (see below).

  I expected this case to follow a 'normal' issue life-cycle, and the case study showed that the air pollution life-cycle indeed followed a standard ('normal') sequence of phases. Yet, it did not reach phase five in the last analysed period, with the air pollution life-cycle being interrupted in 'phase 4.5', as the issue was institutionalized in the socio-political environment but not in the task environment (see discussion of deviations below). In this sense, from the 1940s to the 1980s, this issue life-cycle progressed through the following phases[174]: $\boxed{1 – 2 – 3 – 4 – 4.5}$. While I could identify each period with a conceptual phase, in each period there were deviations.

  In the first empirical period, the case presented two deviations from the model: attention advocacy *came also from the media* (*LA Times*), and *scientific research* contributed to sense-making efforts. The first point seems a minor

[174] This assessment, as in the other case studies, is based not only on the analysis of the dynamics of issue-related pressures, but also on the analysis of the dynamics of industry responses (see next research question), as I have indicated in the pattern-matching analysis in Chapters V-VII.

deviation, in that the model posits action by 'affected groups, citizens, and other activists' and in the case activism came from concerned citizens *and* the media – so, the underlying process of attention advocacy through activism in civil society was present. However, it highlights the importance of the media in drawing attention to problematic conditions. Regarding the second point, the model does make explicit reference to new scientific understandings contributing to a shared sense of urgency *in phase 2*, but this second deviation is an important one, because scientific research not only started *in the first period* but in fact directly contributed to an issue framing that posed a threat to the car industry (cars were identified as the source of the problem). Moreover, this same underlying process of science influencing the issue-framing in early periods was present in the car safety and climate change issue life-cycles (see below), indicating the need to incorporate it in the specification of the model.

A third deviation happened in period 3, when there was no spillover to (niche) markets, something that also did not happen in the fourth and fifth periods. This seems a substantive deviation. While the DILC-model proposes that spillovers to mass markets may happen not only through a slow process of building up demand but also through regulation, it is expected that niche markets will emerge before regulation is enacted. This deviation is a reason why the issue did not move beyond phase 4.

Another more substantive deviation happened in the fifth period, when the issue was interrupted by decreasing pressure from public opinion and policy-makers. The model does posit declining pressure and attention to the issue in phase 5, due to the institutionalization of the issue both in the socio-political (institutional) and in the economic (task) environment. In this case, institutionalization only happened in the socio-political environment. The decreased pressure and attention was due to incumbents drawing on competing (economic) issues and on changes in the macro-context (rise of the anti-regulatory discourse) to avoid further regulatory developments on air pollution. I shall return to these deviations to nuance the research question.

- <u>Automobile safety and the American automobile industry (case study 2):</u> The first period of the automobile safety life-cycle was about the emergence of the issue in civil society (as in phase 1), through the action of activists. Initial public concerns led to sense-making activities – the main process at work in the period, which fits well with phase 1 – and led to an early issue framing (based on the '3E': driver *Education*, law *Enforcement*, and road *Engineering*), which however did <u>not</u> pose a threat to the car industry. The key processes in the second period matched well with pressure dynamics in phase 2: increasing public attention to auto-safety, which caused the issue to spillover to the political arena. The third period, however, represented an interruption of the automobile safety life-cycle, due to the Second World War. The fourth period was very complex: it was primarily about framing struggles (phase 2), as a new technical framing emerged; but it also contained elements from phase 1 (new sense-making leading to emergence of the new problem definition, informed by scientific research on crash-engineering and advocated by doctors); phase 3 (defensive hedging by automakers; small firms deviating from the closed industry-front – see discussion of next answer); and phase 4 (involvement of macro-politicians). Despite this complexity I assess the period as akin to phase 2, due to the prominence of the framing struggle. The fifth period showed an underlying dynamic that fits well with phase 3: although public attention initially stayed at moderate levels, the issue spilled over to the political debate (which was a highly visible framing struggle), leading in turn to a surge in public attention by the mid-1960s. The design-oriented approach to safety gathered pace and influenced policy-makers, who engaged in increasingly heated debates in investigative hearings, until a strong safety act was enacted in 1966. The sixth period presented a dynamics that fit well with phase 4: the safety issue spilled over to the task environment when the implementation of regulations and safety standards began; but spillovers to consumers remained limited, and public attention to safety decreased following the 1973 oil shock and subsequent recession. Developments in the seventh period indicated a *return to phase 3* of the DILC-model: the core dynamic was a new framing struggle in the *political* arena (about the passive restraint standard), which resulted in increasing public attention. In the eight period, the auto-safety issue life-cycle seemed to have moved forward again, presenting new dynamics that fit with the model's phase 4: regulatory 'frame conditions' were changed with states introducing seatbelt use laws; and, more importantly, safety concerns became part of consumer preferences, which created market demand for safety features. In the final (ninth) period, the auto-safety issue spilled over to mainstream markets, with demand for safety spreading to mainstream customers, as in the model's phase 5.

So, automobile safety life-cycle in the United States followed a more complex pathway (the case being divided into *nine* analytical periods was already indicative of this), as the issue did not always progress in the 'right' direction: some periods represented a move 'backwards' to earlier phases. The case thus did *not* follow the 'normal' sequence of phases – the nine periods (from 1900 to 2000) corresponded to the following sequence: 1 – 2 – interruption – 2 – 3 – 4 – 3 – 4 – 5, which suggests the auto safety life-cycle was *interrupted* (during World War II) and later followed a *cyclical*[175] path until it reached phase 5.

So, my empirical investigation did reveal the existence of the interrupted pathway, and the cyclical pathway, confirming part of Bigelow's *et al.*'s (1993) typology. I also contributed to nuance their list of factors interfering with an issue life-cycle, by identifying (in Chapter VII) dynamic processes (causal mechanisms) that cause an issue to deviate from the 'normal' DILC-model pathway: (1) changes in interpretations and framing; (2) changes in the orientation and relative strength of issue-proponents and issue-opponents; (3) alignment with or competition from other issues; and (4) changes in macro-contexts. While the DILC-model accounts for the first two mechanisms, the third and fourth represent aspects that could be incorporated to it. I will return to this point in the discussion of possible nuances and refinements in section VIII.3.

Despite a relatively good match between periods and phases, there were also deviations (see also pattern-matching analysis at the end of the case study). Certain empirical periods were rather complex, displaying conceptual mechanisms from multiple theoretical phases. Some deviations due to empirical complexity are expected, because the DILC-model, based on which I gave the conceptual answer above, is an *ideal-type* model, and, as such, should

[175] As explained in Chapter II (p. 36), a *cyclical* path is one in which the issue cycles back and forth through phases until it reaches a resolution, i.e. in the case of the DILC-model, industry regime reorientation around the issue.

be used as a heuristic tool. Yet, the case study revealed four important deviations that warrant nuancing the conceptual answer and refining the model: (1) outside professional communities and scientific research, which developed a new problem-framing in the fourth period, were more important than social movements (as proposed in the model) in getting car design on the safety agenda; (2) changes in the interpretation of auto-safety (behavioural vs. technological framing) influenced the *direction* of issue-evolution, and at times – most notably, in the fourth period (1946-1955) – it was as if two issue life-cycles were at work; and (3) competing issues (air pollution, car quality concerns, scandals about secret recall campaigns, Japanese competition, car styling, profitability problems) and changing macro-contexts (Great Depression, Second World War, rise of an activist culture, energy crises, economic recession, demographics, health and safety movement, micro-electronics revolution) positively or negatively influenced car safety life-cycle dynamics.

- <u>Climate change and the American automobile industry (case study 3):</u> The first period of this case displayed dynamics that fit well with DILC's phase 1: sense-making processes regarding climate change; and environmentalists (but also scientists) engaging in attention advocacy. The second period displayed dynamics that had a relative good match with phase 2: increase in public attention; and symbolic political engagement at the Federal and global levels. In the third period, public attention to climate change further increased; and a market niche emerged for alternative-fuel vehicles (AFV). The period therefore present dynamics in line with phase 3. The fourth period contained elements from phase 4 – increased attention, new regulations, and growth of the AFV market niche – but also from phase 3 – regulations, while enacted, where not yet strong enough to force industry reorientation, and while the market niche grew, it was still too small to incentivize the industry to reorient. In the fifth period, this pattern seemed to have repeated itself, with processes pointing to contradictory directions: on the one hand, climate change was addressed at the macro-political level (Obama administration), so that executive activity was high; on the other, public attention diminished, regulations were still not strong enough, and the market niche remained small. So, the fourth and fifth periods can be characterized as between phases 3 and 4.

This analysis reveals that the climate change issue life-cycle in the American automobile industry progressed through the following phases from 1979 to 2012: 1 – 2 – 3 – 3.5 – 3.5. So far, this life-cycle seems to be following a 'normal' pathway, in which processes have progressed in the 'standard/normal' direction (therefore, contradicting my initial expectation). Yet, it is currently stuck between phases 3 and 4 ('phase 3.5'), due to absence of strong piece of regulation and consumer demand that could make the industry converge towards a single (radical) technical solution.

Some periods also showed deviations from the conceptual pattern: in the first period, there were two deviations, as (1) a social (environmental) movement already existed and (2) there was early symbolic action, influenced by climate science and by politicians (some of which acting as issue-advocates). In the second period there were two other deviations: (1) California enacted a strong piece of regulation (the 'Zero-Emission Vehicle mandate') that created *substantive* pressure on the car industry (such pressure is expected only in phase 4); and (2) symbolic political engagement at the federal level soon became a hot political debate (which is expected in phase 3). In the fourth period, political pressure was limited and the market niche for alternative-fuel vehicles remained small, i.e. there was low market pressure (both factors contributed to an assessment that the period corresponded to 'phase 3.5'). And in the fifth period, public and political attention were drawn away from climate change due to the financial crisis; regulation was not strong enough to drive radical innovations (electric cars) to mass markets; and the market niche for electric-drive vehicles even *declined* (albeit it grew again in 2012).

All those deviations seem to be due to the following mechanisms: (a) fluctuating levels of attention (which was influenced both by internal life-cycle dynamics, e.g. denial campaigns, and by competing issues such as the financial crisis); (b) multi-level (international and in California) policy developments (which led to fluctuations in the relative strength of issue proponents and opponents); and (c) influences from wider industry contexts and other issues (such as safety, energy security, or the financial crisis, all of which used by the industry to resist change). I shall return to these deviations and mechanisms below to nuance the first answer and propose improvements to the model.

In spite of deviations from the 'normal' pathway found in cases studies 2 and 3, I conclude that, overall, the DILC-model presents internal validity *on the pressure side*, because (a) empirical periods had a relatively good fit with a conceptual phase and (b) most deviations from the 'normal' pathway could be explained with recourse to causal mechanisms posited by the model. Because the three cases also were chosen so that they varied in key characteristics ('maximum variation' case selection criterion), the case studies also demonstrated the versatility[176] of the model. I believe however that some substantive deviations, together with some recurrent findings, warrant nuances to the conceptual answer and refinements of the model (see section VIII.3).

VIII.2.2. Research question B

How do industries respond to changing pressures around societal issues, in terms of technological, political, cultural and economic strategies?

In the DILC-model, industry response strategies to societal problems also progress through phases, as issue-related pressures increase. Firms-in-industry initially downplay or deny the problem, in response to activist pressures (phase 1). As an issue framing that poses a threat to the industry emerges, the industry deploys collective defensive strategies geared towards the institutional environment through the formation of a *closed industry-front* ('Inter-Organizational Relationship' – IOR) (phase 2). In this phase, escalating pressures from different domains tend to make denial ineffective, so that individual firms start to engage in incremental (symbolic) innovations that stay within the bounds of the industry regime. Collectively, and as pressure grows substantively in the political domain, they also engage in collective political strategies to contest (or influence) the official issue framing, giving rise to a highly visible framing struggle (phase 3). Tensions between individual and collective strategies become unsustainable when

[176] Versatility means "the degree to which [a conceptual model] can encompass a broad domain of developmental patterns without modification of its essential character" (Poole *et al.*, 2000, p. 43). In this thesis cases, the versatility of the DILC-model means it was able to 'encompass developmental processes' associated with issue life-cycle that followed distinctive pathways.

the issue spills over to the economic environment (starting in phase 3 with outsiders and concerned consumers exerting pressure). Competitive games are played out between individual incumbent firms and outsiders, due to a growing market niche or due to the implementation of strict regulation (phase 4). If spillovers to the task environment are happening due to a regulatory mandate, the industry may deploy confrontational strategies: play strategic games with regulators (to make the regulation void) or challenge regulation in courts. Yet, if confrontational strategies fail to stop issue life-cycle progression, and, thus, regulatory and market pressures build up, individual firms will start responding with new economic positioning strategies, thus departing from the closed industry-front, which, in this phase 4, will crumble. The ensuing innovation race, when individual firms (incumbents and outsiders) compete in terms of innovations, may accelerate the spillover process to the economic environment, leading to increased mass market demand for new technologies (phase 5). The result of this process is the reorientation of the industry regime.

Discussion of match and mismatch between empirical cases and conceptual pattern. The three cases also presented a relatively good fit with the DILC-model's overall logic of how industry responses to societal issues evolve. But minor and major deviations were also found:

- <u>Local air pollution and the American automobile industry (case study 1):</u> In the first period, the car industry largely ignored the issue or denied its involvement, a dynamic that fits the conceptual phase 1. The second period fit well with phase 2: the industry responded to the new issue framing that pointed to cars as air pollution sources by creating collective organizations (the *Air Pollution Foundation*; Automobile Manufacturers Association's *Vehicle Combustion Products Committee*) to investigate the problem; these associations also represented a 'closed industry-front' to defend the industry regime. The third period matched well with phase 3: while the industry still resisted regulation collectively, with information, lobbying and other framing strategies, individual automakers also made incremental engine improvements, and pursued some defensive hedging towards alternative solutions such as catalysts. The fourth period was of regulatory implementation struggles between regulators and the industry, but the CAA also led the industry to increase R&D investments and patenting. Cracks appeared in the industry-front as General Motors (GM) became a product champion for catalysts and sought first-mover advantages. In this period, the industry's technical regime changed substantially, as expected in phase 4. This period therefore matched well phase 4, but it also presented deviations (see below). The final (fifth) period also deviated from the general pattern, as further changes to the industry regime did not follow the changes in the technical element – I thus assessed that the air pollution life-cycle only reached 'phase 4.5' in the period under consideration. This analysis of how industry response evolved in the air pollution case is in line with the analysis of how issue-related pressure evolved, confirming that the air pollution life-cycle followed a 'normal' sequence of phases, but without reaching phase 5.

While incumbent's strategic responses fitted well with the conceptual pattern, there were a few deviations from the 'normal' DILC pathway. In the second period (akin to phase 2), Ford departed from the closed industry-front by carrying out R&D on a more radical technical solution (catalytic converters), which would be expected in phase 3. In the fourth period, even though the industry-front was then opening up, with GM becoming a champion of catalytic converters, the industry *collectively* counter-mobilized against air pollution regulations when they faced financial problems (in the late 1970s). As no market for low-emission cars emerged (as expected in a ideal typical phase 4), competitive games between outsiders and incumbents were played out during the fourth period more on the institutional environment than on the market. A substantive deviation happened in the fifth period: while the technical and regulatory elements of the regime changed, there was no comprehensive reorientation in foundational beliefs and mission. These substantive deviations in periods 4 and 5 can be explained by lack of changes in consumer preferences (there was no effective demand even from 'concerned consumers').

While the model supposes two routes – regulatory and incremental building up of demand – leading to spillovers to mass markets, it seems that *these processes are both necessary in the life-cycle process for a full industry regime reorientation to happen*. This notion seems to be confirmed also by findings from the case study on car safety (see below). The other two deviations (Ford's early research on catalysts and GM's becoming a champion of catalytic converters) in fact confirmed a key mechanism (conceptualized in the DILC-model) driving the issue forward or impeding its progress: the closing-down and opening-up of the industry-front. On the one hand, Ford's deviation happened when the industry-front was still closed, and thus was resisted by the rest of the industry. On the other, GM's initiative came when AMA's *Vehicle Combustion Products Committee* had already been dissolved, and amidst mounting pressures from outsiders (suppliers and foreign competitors). The initiative therefore was not only made possible by the opening up of the front, but in fact represented the 'burial' of the closed industry-front. Afterwards, GM, Ford and Chrysler diverged in their political positions regarding emission standards, and all accelerated R&D efforts (see Figure V.3.d). Even though the air pollution life-cycle did not move to phase 5, the dissolution of the closed industry-front represented an important development that enabled changes in the industry regime's technical element.

- <u>Automobile safety and the American automobile industry (case study 2):</u> Industry response in the first period, when the automobile safety emerged as an issue, deviated from the conceptual pattern, as there were no 'denial' strategies (see below). In the second period, the industry deployed some incremental innovations, and formed an IOR (the *Automobile Safety Foundation* – ASF) that created a closed industry-front (which endorsed the 3E framing). The period thus seemed to match phase 2. In the third period, the Second World War interrupted the automobile safety life-cycle (with the industry contributing to the war effort). In the fourth period, the industry engaged in a public framing struggle (as in phase 2): through the ASF, it contested the emerging technical framing (focused on car design) by defending the 3E approach. In the fifth period, while this framing struggle became more visible, as it moved to the political domain where the industry strongly defended its position with collective public relation and political strategies, individual automakers began to hedge by setting up safety departments to carry out R&D. These processes therefore match phase 3. The industry response dynamic in the sixth period fit well with phase 4: while individual automakers speeded up R&D and innovation efforts in more radical technologies (anti-lock braking systems

(ABS), airbags) and deployed innovations in response to the implementation of the 1966 safety act, it collectively resisted further tightening up of regulation with confrontational strategies. Yet, GM's initial support to airbags caused a crack in the industry-front (as in phase 4). But industry response in the seventh period indicated the issue moved backwards to phase 3: there was a highly visible political framing struggle (about the proper 'passive safety' technology, and whether regulations were cost-effective), with incumbents forming an informal 'closed industry-front'. In the next period, industry strategies pointed to a move forwards to phase 4: with pressures coming from outsiders (namely, Mercedes, which was successfully selling safety) and with safety concerns becoming part of consumer preferences, significant cracks appeared in the industry-front, and individual firms began to jockey for position in the market that now demanded safety features. The final (ninth) period is close to the conceptual phase 5: as auto-safety issue spilled over to mainstream markets, the American automobile industry regime fully reoriented, with the inclusion of safety in core beliefs and missions.

This account is in line with the analysis of how car safety-related pressures evolve and confirms the interrupted cyclical pattern. It shows that incumbent's strategic responses deviated from the conceptual pattern in early periods; when the issue was interrupted; and when it cycled back to an earlier phase. But in the final three periods, the response pattern adhered to the conceptual logic. In the first period, deviations were due to the absence of denial campaigns, because the industry *accepted* the 3E-framing, which posed no threat to it. The complex fourth period (after the interruption by WWII), which I analysed as more akin to phase 2, contained two elements from phase 3: new entrants exerting pressure on the regime by developing safety innovations and defensive hedging by incumbents (which established safety research departments). In the fifth period, which had mostly phase 3 elements, Ford responded with safety innovations in an attempt to gain a competitive edge – this was not a response to the safety issue as much as it was a response to market competition with Chevrolet (GM). Yet again, the remainder incumbent industry, and GM, in particular, resisted Ford's initiative and apprehended it, re-closing the front in relation to safety. The sixth period was of implementation of regulation (thus, akin to phase 4), but still there was no visible demand for safer cars. Only in the subsequent period, when the life-cycle moved back to phase 3, demand for safety features emerged, initially in luxury markets. Thereafter industry responses followed the conceptual pattern: breaking up of industry-front and competition in markets (eight period/phase 4) and full reorientation of the regime (ninth period/phase 5).

My analysis in Chapter VI identified four mechanisms leading to an interrupted and cyclical path (see discussion of previous answer, case 2); in the case of deviations in the response side, they may be explained by changes in interpretations and framings, and by changes in the orientation and relative strength of issue-proponents and issue-opponents. For example, pressure by new entrants, hedging by incumbents, and Ford's departure from the industry-front were mainly caused by the emergence of a new framing (and Ford's initiative, by an interpretation that it could gain market share from advertising safety). Moreover, the emergence of consumer demand seems a key mechanism behind changes in the strategic orientation of the industry regime, as until the 1980s, regulation alone was not sufficient to cause this reorientation, confirming the notion that I raised in the previous discussion of case study 1.

- <u>Climate change and the American automobile industry (case study 3):</u> In the first period, the car industry remained indifferent to climate change, as there was no visible pressure on it (this period is thus akin to phase 1 mainly due to dynamics on the pressure side). A key development of the second period matched phase 2: the industry joined the *Global Climate Coalition* (GCC), which represented a closed industry-front that deployed defensive strategies in response to climate change-related pressures. In the third period, automakers acknowledged the problem (abandoning the GCC), but continued to politically oppose regulations, and set up a new IOR in the task environment, the *Partnership for a New Generation of Vehicles* (PNGV). Yet, they moved towards technology hedging strategies, while still maintaining their overall commitment to the internal combustion engine (ICE). So, the response pattern in the third period seems to fit well with phase 3. In the fourth period, spillovers to the economic task environment through the emergence of market niches for low-carbon technologies led to a further opening up of the industry-front in the task environment and innovation races in fuel cell, hybrid and biofuel technologies. Yet, the American automobile industry's innovation strategy continued to be centred on the incremental development of the ICE (with advanced technologies (aICE) and biofuel/flex-fuel vehicles (FFV)). Individual American automakers invested in more radical alternatives, but did not fully commit to any option for fear of making the wrong bet (which was reinforced by the experience of hype-cycles). Therefore, while automakers developed new competences and acquired new capabilities, at the industry level, these changes did not amount to a reorientation of the industry regime. The response pattern in this period therefore is in-between phases 3 and 4. In the fifth period, the political position of American automakers weakened (because of bankruptcy and bailout), which made them more receptive to social and political expectations about fuel efficiency and climate change. Individual automakers jockeyed for position with various low-carbon technologies, leading to high patenting activity across multiple categories. Nevertheless, the industry remained committed to an innovation strategy centred on aICE technologies and biofuels/FFV. So, the industry response strategy in this fifth period was still between phase 3 and 4: although American car companies continued to invest in radical green options (e.g. fuel cell or battery-electric vehicles), they did not fully commit to any of them. As in the historical case studies, the pattern of industry response in the climate change life-cycle is in line with the analysis of how climate change-related pressures evolved: it followed a 'normal' sequence of phases, but is stuck between phases 3 and 4, i.e. in 'phase 3.5'.

Industry response during empirical periods deviated in some aspects from the conceptual phases. A first deviation appeared in the second period (identified as phase 2), which contained elements of phase 4: GM developed a radical innovation (the *Impact* electric vehicle) and triggered an early race around the technology. This development was not so much a response to issue-related pressures as it was an attempt by GM to show technological prowess (symbolic strategy). Indeed, subsequently, the incumbent industry formed alliances – namely, the *US Advanced Battery Consortium* (USABC) and the

Partnership for a New Generation of Vehicles (PNGV) – that closed the industry-front in the technology domain (task environment).

In the third period (which I analysed as akin to phase 3), the emergence of the 'win-win' discourse and increasing public concern with the issue led incumbent automakers to abandon the *Global Climate Coalition* (GCC) – while this seemed to represent an early opening up of the industry-front in the institutional environment, in practice incumbents continued with defensive political and technological strategies. But as outsiders (Japanese manufacturers) secured a first-mover advantage in the hybrid-electric vehicle (HEV) market niche, later in this third period incumbents departed from the industry-front in the task environment (also earlier than expected), each adopting a different technology hedging strategy. So, the period also contained phase 4 elements and processes.

In the subsequent period, incumbent American automakers did innovate with HEV models, but their technology strategy was still firmly committed to the incremental development of the internal combustion engine (ICE). Moreover, the co-existence of multiple technologies competing for attention from policy-makers and consumers meant that the industry regime (technical element) did not reorient towards a dominant technical solution, because individual automakers were reluctant to fully commit to any option, still fearing commitment to the 'wrong' technology. In the fifth period, the industry faced severe financial problems, so that, initially, American automakers (namely, GM and Chrysler) manifested intention to develop 'green cars' as a way to secure political will. Yet, this strategy was rejected by the *Presidential Task Force on the Auto Industry* (ATF), because of limited prospects for radical alternative-fuel vehicles in prevailing market conditions. Thus, the period repeated the pattern from the previous one, with the industry still preferring to follow a strategy of incremental innovation, and not committing to any single radical option. These findings emphasize that the crucial 'turning point' in the American automobile industry climate change life-cycle did not happen yet. This is a crucial finding (conclusion), which should be further explored in future research (see section VIII.6). It brings about key policy implications, because this important shift from phase 3 to 4 requires the convergence of industry actors (and other stakeholders) towards a dominant solution, which has not yet happened. Public policy should aim at promoting this convergence, for instance.

Based on this discussion, I conclude that the DILC-model exhibits internal validity also *on the response side*, because empirical periods could be identified with conceptual phases and most deviations could be explained with recourse to the models mechanisms. However, nuances and refinements are also warranted based on findings about how the industry responds to societal issues (see next section).

Because in the three case studies, both pressures and responses appeared to match the same conceptual stage, a key conclusion of this thesis is that issue-related pressures on industries and industry responses to these pressures do indeed *co-evolve* in stages, as proposed in the DILC-model.

Another general conclusion based on the findings of the case studies is that the closing-down and opening-up of an 'industry front' is a key process leading to delays and accelerations in an issue life-cycle. Industry reorientation towards substantive technological strategies that help address societal challenges seem to only take place if there is no closed industry-front. This is a finding with policy implications that should be explored in further research (see section VIII.6).

VIII.2.3. Research question C

In particular, when and why do industry actors decide to develop substantive technological responses?

In phase 1, industry actors do not develop technologies in response to the issue; in phase 2, they only develop incremental innovations, which are a symbolic response to institutional pressures, in line with the creation of a defensive IOR (industry-front) against the issue. The development of substantive technological response to an issue begins with hedging strategies (exploring new domains and technological solutions) in *phase 3* of the Dialectic Issue Life-Cycle's 'normal' pathway: firms in the industry begin to explore new fields to gain the knowledge about how to develop radical technologies, *in case it becomes necessary to market these*, due to a possible regulatory mandate and to prospective changes in mass consumer preferences. But the shift towards substantive technological responses (radical innovation) really happens in phase 4, after the dissolution of the previously closed industry-front, and phase 5, due to both regulatory pressures and market pressures (from outside competitors and consumers). Therefore, the reasons why industry actors initially decide to develop radical technologies are two-fold: (1) the first cause is that the issue begins to affect their secondary involvement arena, posing an indirect threat to their shared identity: the industry begins its learning process to develop these technologies *before* they become mandated/demanded – although this institutional pressure represents a so-called 'distal cause', it is nevertheless a 'necessary' one (Van de Ven and Poole, 2005); (2) the second cause is actually what leads to the radical *innovation*[177]: the industry deploys a radical innovation in response to a societal issue because (and only when) the issue affects its primary involvement arena; in other words, because/when the issue spills over to the task (economic) environment (either due to the implementation of a strong piece of regulation or to the existence of significant demand). This spillover to the task environment is an 'immediate' and 'necessary' cause (*idem*).

Discussion of match and mismatch between empirical cases and conceptual pattern. All three cases fit relatively well with this conceptual pattern, but they also presented important deviations:

- <u>Local air pollution and the American automobile industry (case study 1):</u> The industry started to develop more radical technologies in the third period/phase 3; the oxidation catalyst innovation only came to market during the implementation process (phase 4) of the 1970 CAA; and the three-way catalytic converter (an architectural innovation that contained radical innovations such as an electronic sensor) was only deployed in the fifth period, when the closed industry-front crumbled. One important deviation was that Ford began research on catalysts already in the second period (phase 2), i.e. it began investigation of more radical technical solutions earlier than expected.
- <u>Automobile safety and the American automobile industry (case study 2):</u> Chrysler (second period/phase 2) and Ford (fourth period/phase 2) both innovated with safety features, departing from the industry-front, but these were still incremental innovations. In fact, Chrysler's response was connected to lobbying by Dr. Claire Straith, i.e. a response to pressures from the institutional environment. And Ford's strategy was a response not to the safety

[177] The previous distal cause may be regarded as the trigger for the technological *invention* process.

issue itself but to market (competition) issues. More substantive technological innovations were only brought to market during the implementation of the 1966 car safety act, with Chrysler innovating with an early version of anti-lock braking system (ABS) and GM, with airbags. However, the industry, as a whole, only used substantive (innovation) strategies in the late 1980s, when marked demand for safety was significant.

This case actually revealed that the causality – as implied in my conceptual answer – indeed seems to be from 'industry front opening up' to 'substantive response by incumbents', because in two episodes, when the industry-front was still closed, the industry as a whole did not engage in substantive response: in the 1930s, Chrysler innovated with passenger protection features, but it remained committed to the regime, not referring to safety in advertisements – and the rest of the industry did not follow the initiative; in the 1950s, when Ford attempted to gain a competitive edge with safety features, it was constrained by GM, which managed to keep the front closed. On the other hand, in the 1980s, with pressure coming from an outsider (Mercedes-Benz) and with new consumer demand for safety, the industry-front crumbled and all industry actors engaged in substantive responses. By the 1990s, all elements of the industry regime had been reoriented around safety.

- <u>Climate change and the American automobile industry (case study 3):</u> This case presented a significant deviation from the conceptual pattern, as in the second period GM deployed a substantive technological strategy (a radical innovation, an electric vehicle), which was followed by electric vehicle technology being developed by the rest of the industry (a first technology hype-cycle around battery electric vehicles). From then on, the industry developed both incremental and radical innovations (e.g. advanced ICE technologies, flex-fuel vehicles, HEVs, BEVs, fuel-cell prototypes). The development of both incremental and radical innovation by incumbent industry actors therefore began in the second periods and continued throughout the life cycle.

While the cases matched fairly well the conceptual answer, in terms of the proposed causal mechanisms, the deviations in the third case seems to make a refinement to the DILC-model warranted, because it puts into question its sequential view of technological development.

VIII.3. NUANCES AND REFINEMENTS

VIII.3.1. Nuances and refinements based on discussion of research question A

Three refinements/nuances need to be made regarding the answer to the first research question. The first refinement regards issue framing, different actors' interpretations, and meanings attached to the societal issue (processes and aspects that came out more strongly in case study 2). While the DILC-model incorporates the process of 'construction' of a societal issue as such, and posits[178] this process in phase 1, the case studies showed that framing and reframing of an issue is a continuous process present in all phases of the life-cycle.

For instance, the issue of air pollution, initially viewed as an acceptable nuisance from economic progress, was, in the first period, framed by the media and others as a problematic condition; in the second period, new scientific understandings showed that the issue was caused mainly by cars (and not stationary sources); in the third period it received a stronger 'health-threat' framing (influenced by science and voiced by social movement organizations); in the fourth and fifth periods, when new regulation (the 1970 Clean Air Act) was being implemented to bring emission-control technologies to markets, the industry tried to attach an economic framing to the problem (calling for cost-benefit analysis that included non-pecuniary costs such as fuel economy penalties).

In the case of car safety, the initial framing was that the problem was a matter of driver's education, road engineering, and law enforcement – the 'triple E' framing, supported by industry and safety organizations, which dominated the discourse until the 1950s. After the second World War, a new technical framing emerged, influenced by research on crash-protection and crash-worthiness engineering, which was promoted by professional communities (engineers and medical doctors) and advocated by activists such as Ralph Nader. This technical framing was then adopted by the 1966 safety act, during whose implementation the industry again tried to attach an economic framing to it.

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[178] See specification of phase 1 (Chapter III): "Affected groups, individual citizens, and other activists […], feeling a sense of urgency, first articulate concerns about a critical situation and frame it as a problematic condition. Issues are initially ill-defined and fuzzy; concerned activists do not fully grasp the implications of the facts that gave rise to the issue: there is much uncertainty about causes and consequences, so that these groups engage in sense-making…"

And in the climate change case, in the first period there was an emerging scientific framing influencing the discourse of social movement organizations and politicians, against which in the second period the industry deployed denial strategies that played on scientific uncertainties ('there's no scientific proof of climate change'). It later abandoned the denial stance in favour of an economic framing, calling for market-based mechanisms to address climate change and contesting the economic efficiency of addressing it through innovation for lack of demand (i.e. it was not cost effective in prevailing markets to sell alternative-fuel vehicles).

So, the first nuancing to the DILC-model and first conceptual answer is that framing begins in phase 1, but it is an important *continuous* process that causes changes in direction, accelerations and delays in the issue life-cycle.

The second refinement, connected to the first one, is that scientific research plays an important role both in early sense-making efforts and in this continuous framing process. In the three cases, scientific research and new theories have resulted in the emergence of a 'technical framing', i.e., one that calls for technological solutions – such as catalytic converters and safety features – and/or contests the use of certain technologies, such as the internal combustion engine (and thus advocates the use of alternative technologies such as electric-drive vehicles). This is key in moving the industry out of their zone of indifference and triggering an open 'dialectical processes' (struggles between issue-proponents and issue-opponents).

Moreover, in the three cases scientists played an active role: in the air pollution case, Prof. Haagen-Smit's (who also served as a public official in Los Angeles) research was key in associating smog to cars, and later, science also played a role in portraying air pollution as a health hazard; in the car safety case, the active role was played by individual researchers/scientists (Hugh De Haven; Dr. Claire Straith), and two community of professionals (crash engineers and medical doctors); and in the climate change case, the role is being played by the international community of climate scientists

So, the second nuancing to the first research answer is that science also plays a *continuous role* in the issue life-cycle process. I also propose a refinement to the specification of phase one to include action by scientists: "Affected groups, individual citizens, scientists, and other types of activists, feeling a sense of urgency, first articulate concerns about a critical situation and frame it as a problematic condition. Issues are initially ill-defined and fuzzy; concerned activists do not fully grasp the implications of the facts that gave rise to the issue: there is much uncertainty about causes and consequences, so that these groups engage in sense-making which may be influenced by scientific research".

The third nuancing regards the role of (a) competing issues, i.e. factors *external* to the dynamics of the focal issue life-cycle, yet *strategic* to regime actors and thus affecting and affected by industry regime developments; and (b) macro-contextual developments, i.e. external to the core issue life-cycle dynamics and to the industry regime. My case studies were indeed structured so as to account for the influence of such factors, and their importance can be illustrated by the role played by economic issues at the regime level (auto industry financial problems in the late 1970s, early 1990s and late 2000s) or cultural developments at the macro level (new environmentalist discourse in the 1960s/70s, broader health and safety movement, rise of women as chief household decision-maker in the 1980s). The model and conceptual answer employed the concept of 'spillover' as a core mechanism through which the issue life-cycle progresses: the issue life-cycle moves forward when the issue, initially confined to debates in one arena (e.g. civil society), begins to be discussed in another arena (e.g. policy domain). This core mechanism cannot fully account for the influence of competing issues and macro-contexts on the issue life-cycle. Instead, a possible *explanans* that could be used to refine the model is the concept of 'alignment' between internal (life-cycle) and external. The incorporation of this 'mechanism' into the model could be the goal of future research.

VIII.3.2. Nuances and refinements based on discussion of research question B

Regarding the answer to research question B, the first nuancing that I propose is in line with the first one outlined above: the fact that framing is a continuous process in the issue life-cycle. Thus, *framing struggles* may occur in all phases (and not only in phase 2), *but only if* the prevailing framing represents a threat to the industry regime. The safety case shows that, in the absence of a threatening framing, the industry will not deploy confrontational framing strategies.

The second nuancing is connected to the third one outlined above: the role of competing issues and macro-level developments, and the need to account for *alignment* of processes. The industry strategically draws on competing issues (playing on supposed trade-offs, e.g. between emission-control or safety and fuel economy; jobs and regulation etc.) and on favourable discourses (e.g. anti-regulation ideology) to delay issue progress. This is a strategic response not yet incorporated in the model that may warrant further research (see section VIII.4).

VIII.3.3. Nuances and refinements based on discussion of research question C

Based on the pattern-matching analysis of the third case study with the conceptual answer to question C, I proposed to nuance the sequential view implicit in the DILC-model (incremental innovation, hedging, diversification/radical innovation, full reorientation), and to problematize the distinction between symbolic and substantive strategies, particularly the notion that radical technology development is necessarily substantive strategy. The third case study, in particular, showed many instances when radical technology development was used as a symbolic strategy towards the institutional environment: e.g. GM's *Impact*, USABC/PNGV, a parade of battery-electric and fuel-cell vehicle prototypes – yet, they all brought about significant unintended consequences, such as the enactment of California's ZEV mandate (influenced by GM's *Impact*) or Toyota's development of the *Prius* HEV (a response to the announcement of the PNGV).

The nuance that I therefore propose is that incumbents can engage with radical innovation in early periods, but are then motivated primarily by symbolic reasons. Does this proposition hold for the historical cases? I argue so, as each contained at least one example of this early development of technologies for symbolic reasons (i.e. aimed at the institutional environment): in the air pollution case, Ford's early research on catalysts (vanadium pentoxide) was keenly publicized in order to secure public and political goodwill, and Chrysler followed suit by announcing development of better tuned engines that produced less fumes. In fact, Chrysler's incremental 'Clean Air Package' was adopted by the incumbent industry to pre-empt the need and then influence (frame) the content of regulation. In the safety case, early technological developments by Chrysler and Ford were also symbolic and aimed at securing public goodwill ('halo effect') through what mainly amounted to public relations or marketing strategy. A refinement to the DILC-model is thus to include as a possibility the development of more radical innovation in the second phase, but as a symbolic response to institutional pressures.

VIII.4. EVALUATION AND DISCUSSION OF THE COMBINED QUANTITATIVE-QUALITATIVE METHODOLOGY

In Chapter IV, I proposed a novel mixed-methods approach to investigate the relationship between issue life-cycles and issue-attention cycles (including technology hype-cycles). The case studies showed the usefulness of these methods, and that attention indicators can be fruitfully used to generate first insights about relationships and developments. The combined analysis of quantitative attention indicators and of qualitative material revealed that the dynamics of attention is indeed connected to issue life-cycle dynamics.

Visual analysis of indicator charts was employed in all case studies, in order to help structuring the narrative approach ('temporal bracketing'). This was the only quantification approach used in the air pollution case study, which did however help to establish initial patterns and relationships that were later explored in the narrative analysis. I noted, however, that this method rested on my subjective judgement, and therefore I used in combination with qualitative criteria for identifying different periods. The method, used in combination with other quantification approaches, was also fruitfully employed in the second and third case studies.

In the second case study, I also employed a correlation analysis of attention indicators, which revealed interesting 'within period' relationships (that were further explored in the narrative analysis): (a) early connection between public and political attention with the 'objective' side of the issue (i.e., number of car-related fatalities) (which indicated sense-making and framing processes); (b) disconnection between attention indicators and the 'objective' side of the issue later on in the life-cycle (with attention indicators more connected to visible societal struggles in the institutional domain); (c) technology development in response to the issue being firstly developed by outsiders and later by regime actors (which are initially locked in by the regime); and (d) a connection between outsiders' and incumbents' technology development towards the end (phases 4 and 5) of the issue life-cycle (indicating an innovation race). A fifth quantitative insight, revealed by the visual inspection of attention indicators, was not explored in the correlation analysis and represent an area for future research (see section VIII.5): the co-evolution of problem framings and technical solutions seems to have been captured by attention indicators (media usage of issue-related terms and patenting by types).

The third case study showed the full potential of the novel mixed-methods approach. The statistical analysis seems to have confirmed that the visual examination is in itself a valid method to devise a temporal bracketing structure, because the visual insights were corroborated by the statistical test for structural breaks (QLR test). The meta-analysis of correlation matched the DILC-model's overall logic of how issue-related pressures evolve, because it revealed that industry attention was firstly (up to the second period) correlated to *public attention*; then (up to the third period) to *congressional attention*; and later (during the fourth and fifth period) to *executive attention*. In other words, the analysis matched the DILC-model's conceptualization of a 'normal' pathway: initial issue life-cycle dynamics is centred on the public domain, it later spills over to the policy-making (in the case, Congress) domain, and after a law is enacted, to the policy-implementation (executive) domain. While this is an interesting result that emphasizes the analytical potential of the methodology, I note that it must be treated with care, because of the limited power of the statistical (correlation) tests due to the small size of the samples that I used. Indeed, I believe it is always fundamental to complement the analysis with a qualitative approach.

Overall, my assessment is that the methodology that I proposed, combining quantitative and qualitative methods, is particularly useful in applying the framework (the DILC-model) to the empirical cases. The quantitative methods provide a way to structure the empirical case in sub-periods and reveal initial insights into relationships that were subsequently explored through qualitative methods. Yet, the quantitative methods did present some issues. The use of a meta-analysis of correlations proved problematic in the second case study, mainly due to issues with low quality of data and short time-series. This was circumvented in the third case study, when better quality data was available. The method can still be improved, if instead of yearly data points one uses quarterly or monthly intervals (which will result in larger sample sizes). This kind of analysis of issue life-cycles and issue attention-cycles should be developed and improved, something that is facilitated by increasing availability of public sources of 'big data'.

VIII.5. CONTRIBUTIONS AND ORIGINAL CLAIMS TO KNOWLEDGE

This thesis makes four contributions to knowledge[179]:

1. In the field of science, technology and innovation (STI) policy research, it contributes by developing a model that improves our understanding of the co-evolution between societal issues, technologies and industries, thus helping to close a long-standing gap in the literature (Nelson, 1977; Morlacchi and Martin, 2009). The DILC-model is an analytical 'ideal type' that includes in its specification how policy problems emerge in the first place (through advocacy and activism in the institutional environment) and evolve (through a dialectical process between issue-proponents and issue-opponents, usually incumbent industry actors). The conceptual model was applied to three case studies, which revealed insights into why some problems remain under-addressed in spite of technological developments: this is due to strong resistance by the incumbent industry to change its practices (industry regime), and to insufficient social, cultural and economic pressures that could incentivise/force the industry to reorient its regime so as to address the issue.

[179] As noted in the *Acknowledgements*, my DPhil research and thesis contributed to the DESTABLE project (ERC grant, no. 204246), led by Prof. Frank Geels, and which also included a second DPhil candidate, (now) Dr. Bruno Turnheim. The DESTABLE project focused on the destabilization of socio-technical regimes as key to transitions towards sustainability. Because destabilization is (was) an under-investigated topic in transitions theory (part of the STI field), the project created opportunity for each team member to develop their own original contributions. While starting with similar, general questions (What is a destabilization process? How do actors enact and respond to this process? What is the role of societal issues in destabilizing a socio-technical regime?), each of us handled them very differently: Prof. Geels reflected on the implications of destabilization processes for the so-called 'multi-level perspective' (MLP), for transitions theory and innovation studies, and for developing and refining the TEF; Dr. Turnheim looked at questions of time/timing in a destabilization process, of multiple levels of change processes, of normativity, and of socio-cultural change (with a focus on the coal industry and the energy field in the UK); and I looked at the organizational-field level, in order to understand industry strategies and the development of technologies in response to pressures connected to societal issues. Furthermore, as I will make explicit in this section, I also developed a novel methodology that allowed me link my theoretical contribution (the DILC-model) to empirical cases.

2. The thesis contributes to issue life-cycle theory, because the DILC-model helps to address three open questions about: (a) the processes through which an industry shifts to substantive responses (e.g. technological strategy); (b) the interplays between firm-level and collective (industry-level) strategies; (c) the relationship between an issue life-cycle and issue *attention*-cycles; and (d) the criteria for the conceptual and empirical identification of issue life-cycle stages. The first two gaps were addressed by mobilizing insights from other fields (STI, Organizational Institutionalism); the third gap was addressed with the development of a novel methodology; and the fourth gap was addressed with the explicit inclusion of qualitative indicators for phase shifts in the development of the DILC-model (Chapter III) and also through the use of the novel qualitative-quantitative methodology.
3. The third contribution is related to item (c) above. In this thesis, I used a *mixed-methods approach* to systematically analyse an array of attention indicators *within an issue life-cycle framework*, something that, to the best of my knowledge (as shown in my literature review), has not been previously done. My assessment is that the methodology was particularly fortuitous. Thus, this thesis' fourth contribution is methodological.
4. The final contribution relates to a contemporary problem (a 'Grand Societal Challenge') and debate, and can be regarded as a policy lesson: the thesis has shown that the climate change issue life-cycle, in relation to the American automobile issue, is at crossroads. A key reason is that the strategy of individual industry actors has not yet converged towards a dominant solution, with many alternative-fuel vehicle technologies competing for domination. This in turn is due to a lack of strong piece of regulation at the US federal level forcing zero-emission vehicles to market, and because effective demand for those vehicles is still low. The full reorientation of the American car industry around climate change will not happen until regulatory and market pressures build up and become aligned.

VIII.6. LIMITATIONS, GENERALIZABILITY AND FUTURE RESEARCH

The contributions of this thesis present at least four limitations, which represent initial areas for further research. Firstly, even though I aimed at 'middle-range' theorization, the DILC-model cannot yet be regarded as a 'middle-range theory' (not the least because it still scores too low on simplicity), and should be tested in different settings (industries, countries) to confirm its versatility, because the theoretical framework was applied to only one context: the American automobile industry. While cases were critically selected to enable testing and improving the model, it may be that some mechanisms were contingent to the American context. Indeed, a study based on the Varieties of Capitalism (VoC) approach (Mikler, 2006) proposes that American carmakers base their strategies on instrumental considerations and thus adopt a confrontational position in face of regulations that call for innovations 'not demanded by consumers'. Mikler (2006) found that automakers in Germany take a more cooperative stance towards governmental and societal demands; while in Japan automakers tend to respond to societal demands with substantive strategies due to a corporate culture that strives for excellence.

Yet, globalization processes appear to have led to a convergence in business strategies (Levy and Newell, 2000), and resistant strategies have been found also in places like Europe (in recent years, for instance, automakers operating in Europe signed a voluntary agreement with the EU to sell cars that meet a certain level of carbon emissions, but did not fulfil it). Notwithstanding, the application of the DILC-model to non-US-based cases is necessary to further test its versatility. Furthermore, it will be interesting to follow a life-cycle process that impacts on multiple industry regimes, in order to investigate how response by these industries (and changes in regimes) co-evolve. Indeed, climate change is an issue that affect multiple industries, and a question to be investigated is whether two (or more) industries are in the same stage or not of the climate change life-cycle.

Ultimately, the application of the DILC-model to more empirical cases and the expansion of its 'case study' base shall allow for the identification of simplified patterns, mechanisms, and processes with the goal of transforming the model into a middle-range theory of how societal issues, industry regimes, and technologies co-evolve. Therefore, the search for and development of a simpler and more elegant model (for instance, a stage-model not based on interrelated propositions but on simplified processes) is an important area for future research.

Secondly, and related to the first limitation, even though issue life-cycle theory has been applied to international cases, the bulk of the literature was developed based on the American context. As this literature is the cornerstone of the DILC-model, it could be that the confirmation of the model's specification was contingent to the cases selected. In the concluding remarks to Chapter IV, I suggested that, in theory, the DILC-model and findings based on it could apply to industries with the following characteristics: (a) economically big and concentrated on few large firms (oligopoly); (b) politically powerful; (c) culturally visible; and (d) supplying differentiated products ('innovations') directly to the final consumer. While the DILC-model and these findings of the thesis could be potentially generalizable to industries such as pharmaceutical and consumer electronics, one important avenue for further research is to apply the model to different countries, industries and issues[180] in order to further test the versatility of the model.

The third limitation (in fact, a set of limitations) refers to the quantification approach. While I have been cautious in making 'definitive' claims based on the quantitative methods, which I therefore complemented with a qualitative analysis, it is important to highlight the limitations of each of the three quantitative methods that I have employed. Firstly, underlying each approach are (attention) indicators, which, by definition, do not capture all qualitative aspects of the real phenomenon or entity it tries to depict. I note, however, that in the second case study, the visual examination of two 'qualitatively differentiated' indicators (media usage of different car safety-related terms and car safety patents by types) showed that the co-evolution of problem framings and technical solutions seems to be captured by more nuanced quantitative data. This insight could be systematically investigated with quantitative methods (e.g. correlation analysis) in future research.

[180] I believe that one increasingly important contemporary issue to which the model could be applied is digital (online) privacy and the responses of the Internet industry. This issue has received an important impetus in 2012, when the former Central Intelligence Agency (CIA) employee and National Security Agency (NSA) contractor Edward Snowden disclosed classified NSA document about global mass surveillance of unsuspected individuals through the interception of Internet and telephone data. Speculatively, I would say that this event is akin to the 'Ralph Nader scandal' in the 1960s, which contributed to the enactment of the strong 1966 safety act. An analysis of this case with the aid of the DILC-model could test this hypothesis and identify in which phase the digital privacy life-cycle is. A key complication, however, is that the online privacy issue threats the legitimacy not only of the Internet industry, but of national governments 'invading' citizens' privacy through mass surveillance programmes. It would be interesting to investigate what are the implications of this fact to the dynamics of an issue life-cycle.

Each quantitative method also presents individual limitations. An issue with the visual inspection of attention charts is that it is based on a subjective interpretation, something that could be addressed if more than one researcher carries out the analysis. The correlation analysis has issues associated to sample size, which limits the power of the statistical tests. As already mentioned, this issue can be countered by using longer time-series with quarterly, monthly, or even daily observations. A second issue with the correlation analysis is that correlation does not imply causality, so that findings have to be compared with theory and qualitative evidence. And, finally, the structural break analysis (the QLR test) has similar limitation to the correlation analysis, related to sample size, which could therefore be addressed in the same way. Future research should aim at improving the novel mixed methodology by refining the quantification approaches.

The fourth limitation relates to the concepts that I have proposed as underlying an issue life-cycle, which represented core mechanisms in the DILC model. These concepts were also used to analyse processes in individual cases, and to help explain deviations between cases and the ideal type model. For instance, I have drawn on the notions of 'spill over' and 'attention threshold' to refer to the process of how an issue, from being confined in one arena (e.g. civil society), starts to be discussed in another arena (e.g. policy-making domain). I also employed the notion of 'dialectics' (e.g. framing or competitive struggles) as the core underlying process in the DILC model. Another example is the concept of 'alignment' between processes, which I raised as a way to refine the model's specification. In my analysis, I have not strictly defined these and other concepts, so that future research should do so and could aim at refining them. This could be done qualitatively, by developing more rigorous definitions based on existing theories, but also quantitatively. For instance, research could aim at establishing what constitutes an 'attention threshold' above which an issue 'spills over' to a different arena.

I also propose four topics for future research that aim not at addressing limitations but to expand the DILC-model. Firstly, in the car safety case, it was as if two life-cycles were happening: one was the life-cycle of the issue *framed as a 3E problem*; the other was the life-cycle of the issue *framed as a technical problem with cars*. As I have pointed out in the nuancing to the first research answer, framing and reframing processes continuously occur in an issue life-cycle, depending on interpretations, theories, and beliefs. I have suggested that these processes lead to changes in direction, and speed in the issue life-cycle. I have not systematically investigated this suggestion, which could be explored in future research.

Secondly, while my case studies did account for influences from external factors (competing issues and macro-contextual developments) on the issue life-cycle, this is something not yet systematically incorporated in the DILC-model. In particular, a recurring finding from the case studies was that economic problems tend to disrupt issue-cycles, i.e. the focal issue 'misaligned' with economic developments. In principle, however, economic problems could represent a window of opportunity for intervention in the industry regime, such as when Chrysler was bailed out in the late 1970s and when GM and Chrysler were rescued in the late 2000s. Future research could investigate multiple issue interaction, in order to refine the model by including 'alignments' and 'misalignments' with external factors as a causal mechanism leading to different issue life-cycle trajectories. As this would entail tracing various institutional and economic developments that affect an industry regime, the investigation could explore theoretical possibilities related to the 'Triple Embeddedness Framework'.

Thirdly, in answering research question C, I proposed that substantive technological responses only happen when the issue spills over to the task environment, due to the implementation of a *strong piece of regulation* or to the existence of *significant demand*. One open question is therefore whether it is possible to distinguish *theoretical routes (sequence of causal mechanisms and processes) that lead to changes in demand and in regulation*. While I have indicated processes leading to changes in regulation in case study 1[181] and processes leading to changes in demand in case study 2[182], I believe that this question can only be fully

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[181] See discussion in Chapter V: "The [1970 Clean Air Act] was the culmination of reinforcing processes, which explain why the local air pollution issue life-cycle followed the regulatory route in the US:
(a) decreasing legitimacy of automakers; (b) increasing political frustration over the industry's delay tactics; (c) macro-cultural trends such as rising environmentalism and social activism; (d) political jockeying between Senator Muskie and President Nixon"

[182] See discussion in Chapter VI: "…new consumer attitudes were related to: (1) public and political debates about auto-safety and over passive restraint regulations; (2) the institutionalization of the health-and-safety movement; (3) demographic changes; (4) consumer education about relative car safety; and (5) car industry (regime actors' and outsiders') advertisements of seatbelts and other safety features. The key mechanisms unifying this process seems to be (a) 'attention advocacy' by activists and social movements and political struggles in the institutional environment and (b) outsiders' strategies in the task environment. While these mechanisms *were* present in the air pollution case, they were active for a couple of decades. So, time (not only

addressed with future research that apply the DILC-model to more cases of industry issue life-cycles. The building up of evidence could reveal whether the processes that I have identified consistently reoccur and in which order.

Finally, the third case study has indicated that the shift from the third to the fourth phase – the 'turning point' in the issue life-cycle process – is the most difficult one. This transition entails, for instance, convergence of industry actors (and other stakeholders) towards a dominant solution. Future research could aim at identifying which processes facilitate or prevent the transition from the third to the fourth phase. In the historical case studies, public attention to the issue escalated to unprecedented levels during the 'turning point', something that seemed to incentivize politicians to enact strong pieces of legislation. Furthermore, a key process that has consistently reappeared in the case studies was the opening up of the 'industry-front' (the dissolution of defensive inter-organizational relationships). This process seems to be associated with an issue life-cycle 'turning point'. What causes a closed industry-front to crumble? And are there other processes facilitating or preventing this crucial transition? These are important questions with practical implications to the development of appropriate policy aimed at addressing 'Grand Societal Challenges'. ■

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timing) and duration of mechanisms also seem important in explaining changes in consumer preferences."

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APPENDIX: STATISTICAL RESULTS

1. RESULTS OF CORRELATION TESTS OF CASE STUDY 2

List of variables:

- fatalities = yearly number of automobile-related fatalities
- bigthree = yearly sum of safety-related patents by General Motors, Chrysler and Ford
- outsiders = yearly sum of safety-related patents by other automakers and suppliers
- publicattention = yearly average of number of articles on automobile safety in the *Chicago Tribune*, *Los Angeles Times*, *New York Times*, *Wall Street Journal*, and *Washington Post*
- congressional record = yearly number of safety-related outputs in the *Congressional Record*
- federalregister = yearly number of safety-related outputs in the *Federal Register*

The correlation analysis was carried out using *Stata 12*.

Results for the whole period [1900-2000]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister, stats(rho p obs) st(.01) pw

  Key

   rho
   Number of obs
   Sig. level

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |      101
             |
             |
   outsiders |   0.7278*  1.0000
             |      101      101
             |   0.0000
             |
  fatalities |   0.6387*  0.7492*  1.0000
             |      101      101      101
             |   0.0000   0.0000
             |
publicatte~n |   0.7617*  0.7125*  0.7850*  1.0000
             |      101      101      101      111
             |   0.0000   0.0000   0.0000
             |
congressio~d |   0.5995*  0.7852*  0.9545*  0.7530*  1.0000
             |      101      101      101      101      101
             |   0.0000   0.0000   0.0000   0.0000
             |
federalreg~r |   0.6615*  0.8621*  0.6330*  0.7913*  0.6912*  1.0000
             |       65       65       65       65       65       65
             |   0.0000   0.0000   0.0000   0.0000   0.0000
```

Results for first sub-period [1900-1924]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1900 & year<1925, stats(rho p obs) st(.
> 01) pw

+-----------------+
|  Key            |
|-----------------|
|   rho           |
|   Number of obs |
|   Sig. level    |
+-----------------+

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000 
             |       25
             |
             |
   outsiders |        .        . 
             |       25       25
             |        .
             |
  fatalities |   0.4478        .   1.0000 
             |       25       25       25
             |   0.0248        .
             |
publicatte~n |   0.2352        .   0.8159*  1.0000 
             |       25       25       25       25
             |   0.2578        .   0.0000
             |
congressio~d |        .        .        .        .        . 
             |       25       25       25       25       25
             |        .        .        .        .
             |
federalreg~r |        .        .        .        .        .        . 
             |        0        0        0        0        0        0
             |        .        .        .        .        .
             |
```

Results for second sub-period [1925-1942]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1925 & year<1943, stats(rho p obs) st(.
> 01) pw

 +-----------------+
 |  Key            |
 |-----------------|
 |   rho           |
 |   Number of obs |
 |   Sig. level    |
 +-----------------+

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |       18
             |
             |
   outsiders |        .        .
             |       18       18
             |        .
             |
  fatalities |   0.4556        .   1.0000
             |       18       18       18
             |   0.0574        .
             |
publicatte~n |   0.1201        .   0.1393   1.0000
             |       18       18       18       18
             |   0.6351        .   0.5814
             |
congressio~d |   0.2455        .   0.5654   0.2624   1.0000
             |       18       18       18       18       18
             |   0.3261        .   0.0145   0.2929
             |
federalreg~r |   0.0606        .  -0.0386   0.4629   0.0195   1.0000
             |        7        7        7        7        7        7
             |   0.8973        .   0.9346   0.2956   0.9670
             |
```

Results for third sub-period [1943-1946]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1943 & year<1947, stats(rho p obs) st(.
> 01) pw
```

Key
rho
Number of obs
Sig. level

	bigthree	outsid~s	fatali~s	public~n	congre~d	federa~r
bigthree	1.0000					
	4					
outsiders	.	.				
	4	4				
	.					
fatalities	-0.4472	.	1.0000			
	4	4	4			
	0.5528	.				
publicatte~n	0.0000	.	0.8000	1.0000		
	4	4	4	4		
	1.0000	.	0.2000			
congressio~d	-0.4472	.	1.0000*	0.8000	1.0000	
	4	4	4	4	4	
	0.5528	.	0.0000	0.2000		
federalreg~r	-0.7071	.	0.9487	0.6325	0.9487	1.0000
	4	4	4	4	4	4
	0.2929	.	0.0513	0.3675	0.0513	

Results for fourth sub-period [1947-1955]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1947 & year<1956, stats(rho p obs) st(.
> 01) pw
```

Key
rho
Number of obs
Sig. level

	bigthree	outsid~s	fatali~s	public~n	congre~d	federa~r
bigthree	1.0000					
	9					
outsiders	-0.2423	1.0000				
	9	9				
	0.5300					
fatalities	0.9048*	-0.4341	1.0000			
	9	9	9			
	0.0008	0.2430				
publicatte~n	0.7730	-0.1703	0.7667	1.0000		
	9	9	9	9		
	0.0146	0.6614	0.0159			
congressio~d	0.7321	-0.0043	0.4770	0.3933	1.0000	
	9	9	9	9	9	
	0.0249	0.9913	0.1942	0.2950		
federalreg~r	-0.5455	0.0000	-0.4140	-0.4140	-0.3118	1.0000
	9	9	9	9	9	9
	0.1287	1.0000	0.2679	0.2679	0.4140	

Results for fifth sub-period [1956-1966]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1956 & year<1967, stats(rho p obs) st(.
> 01) pw

  Key

    rho
    Number of obs
    Sig. level

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |       11
             |
             |
   outsiders |  -0.2924   1.0000
             |       11       11
             |   0.3829
             |
  fatalities |   0.3307  -0.2055   1.0000
             |       11       11       11
             |   0.3205   0.5444
             |
publicatte~n |   0.3458  -0.5974   0.6000   1.0000
             |       11       11       11       11
             |   0.2976   0.0523   0.0510
             |
congressio~d |  -0.2511   0.1868   0.1959   0.4055   1.0000
             |       11       11       11       11       11
             |   0.4563   0.5823   0.5637   0.2160
             |
federalreg~r |  -0.4046  -0.0627   0.6331   0.2752   0.4046   1.0000
             |       11       11       11       11       11       11
             |   0.2171   0.8547   0.0366   0.4127   0.2171
             |
```

Results for sixth sub-period [1967-1976]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1967 & year<1977, stats(rho p obs) st(.
> 01) pw

 Key

   rho
   Number of obs
   Sig. level

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |       10
             |
             |
   outsiders |   0.7038   1.0000
             |       10       10
             |   0.0231
             |
  fatalities |  -0.5771  -0.3354   1.0000
             |       10       10       10
             |   0.0806   0.3435
             |
publicatte~n |  -0.5144  -0.4512   0.8788*  1.0000
             |       10       10       10       10
             |   0.1282   0.1905   0.0008
             |
congressio~d |  -0.5521  -0.4085   0.6970   0.6970   1.0000
             |       10       10       10       10       10
             |   0.0980   0.2411   0.0251   0.0251
             |
federalreg~r |   0.6650   0.9268* -0.3939  -0.3818  -0.3576   1.0000
             |       10       10       10       10       10       10
             |   0.0359   0.0001   0.2600   0.2763   0.3104
             |
```

Results for seventh sub-period [1977-1984]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1977 & year<1985, stats(rho p obs) st(.
> 01) pw

  Key

   rho
   Number of obs
   Sig. level
```

	bigthree	outsid~s	fatali~s	public~n	congre~d	federa~r
bigthree	1.0000					
	8					
outsiders	0.5543	1.0000				
	8	8				
	0.1540					
fatalities	0.6506	0.3095	1.0000			
	8	8	8			
	0.0806	0.4556				
publicatte~n	-0.1807	-0.5952	-0.0714	1.0000		
	8	8	8	8		
	0.6684	0.1195	0.8665			
congressio~d	0.5181	0.8810*	0.3810	-0.6667	1.0000	
	8	8	8	8	8	
	0.1884	0.0039	0.3518	0.0710		
federalreg~r	0.5212	0.0838	0.9341*	0.0240	0.1916	1.0000
	8	8	8	8	8	8
	0.1853	0.8435	0.0007	0.9551	0.6494	

Results for eighth sub-period [1985-1991]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1985 & year<1992, stats(rho p obs) st(.
> 01) pw

+-----------------+
|  Key            |
|-----------------|
|   rho           |
|   Number of obs |
|   Sig. level    |
+-----------------+

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |        7
             |
             |
   outsiders |   0.5946   1.0000
             |        7        7
             |   0.1591
             |
  fatalities |   0.1982  -0.2500   1.0000
             |        7        7        7
             |   0.6701   0.5887
             |
publicatte~n |   0.1261   0.6429  -0.7500   1.0000
             |        7        7        7        7
             |   0.7876   0.1194   0.0522
             |
congressio~d |  -0.9550* -0.6429  -0.3214   0.0000   1.0000
             |        7        7        7        7        7
             |   0.0008   0.1194   0.4821   1.0000
             |
federalreg~r |  -0.0727   0.5225  -0.7748   0.8829*  0.1261   1.0000
             |        7        7        7        7        7        7
             |   0.8769   0.2289   0.0408   0.0085   0.7876
             |
```

Results for ninth sub-period [1992-2000]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1992 & year<=2000, stats(rho p obs) st(
> .01) pw

  Key

   rho
   Number of obs
   Sig. level

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |        9
             |
             |
   outsiders |   0.4352   1.0000
             |        9        9
             |   0.2418
             |
  fatalities |   0.4500   0.5607   1.0000
             |        9        9        9
             |   0.2242   0.1163
             |
publicatte~n |   0.2176   0.7017  -0.1004   1.0000
             |        9        9        9        9
             |   0.5739   0.0351   0.7971
             |
congressio~d |   0.0084  -0.0756  -0.5690   0.1639   1.0000
             |        9        9        9        9        9
             |   0.9830   0.8467   0.1098   0.6736
             |
federalreg~r |   0.4833   0.6360   0.7000   0.0753  -0.1004   1.0000
             |        9        9        9        9        9        9
             |   0.1875   0.0656   0.0358   0.8473   0.7971
             |
```

Results for sub-period [1985-2000]

```
. spearman bigthree outsiders fatalities publicattention congressionalrecord federalregister if year>=1985 & year<=2000, stats(rho p obs) st(
> .05) pw

+-----------------+
|  Key            |
|-----------------|
|   rho           |
|   Number of obs |
|   Sig. level    |
+-----------------+

             | bigthree outsid~s fatali~s public~n congre~d federa~r
-------------+------------------------------------------------------
    bigthree |   1.0000
             |       16
             |
             |
   outsiders |   0.7795*  1.0000
             |       16       16
             |   0.0004
             |
  fatalities |  -0.2992  -0.4474   1.0000
             |       16       16       16
             |   0.2603   0.0823
             |
publicatte~n |   0.6615*  0.8800* -0.7476*  1.0000
             |       16       16       16       16
             |   0.0053   0.0000   0.0009
             |
congressio~d |  -0.6239* -0.6834*  0.1531  -0.5000*  1.0000
             |       16       16       16       16       16
             |   0.0098   0.0035   0.5715   0.0486
             |
federalreg~r |   0.7102*  0.8660* -0.5931*  0.8277* -0.5538*  1.0000
             |       16       16       16       16       16       16
             |   0.0021   0.0000   0.0155   0.0001   0.0260
```

2. RESULTS OF QLR TESTS OF CASE STUDY 3

	Public Attention		Congressional Attention		Executive Attention		Automotive News		Big Three Patents		Outsiders' patents		AFV Market Share	
Year	*QLR statistic*	*Sig. level*	*QLR statistic*	*Sig. level*	*QLR statistic*	*Sig. level*	*QLR statistic*	*Sig. level*	*QLR statistic*	*Sig. level*	*QLR statistic*	*Sig. level*	*QLR statistic*	*Sig. level*
1983	2.77416	insig.	5.30635	10%	0.59358	insig.	n/a	n/a	0.35778	insig.	0.25556	insig.	n/a	n/a
1984	1.89573	insig.	4.09216	insig.	0.64357	insig.	n/a	n/a	0.20986	insig.	0.25873	insig.	n/a	n/a
1985	2.80265	insig.	25.7704	1%	14.4402	1%	n/a	n/a	0.67907	insig.	0.22093	insig.	n/a	n/a
1986	2.17146	insig.	10.1977	1%	4.93987	insig.	n/a	n/a	0.69052	insig.	0.87472	insig.	n/a	n/a
1987	4.32801	insig.	4.88839	insig.	3.12545	insig.	n/a	n/a	1.49487	insig.	4.19361	insig.	n/a	n/a
1988	2.50234	insig.	3.69468	insig.	1.45697	insig.	n/a	n/a	2.03019	insig.	3.44616	insig.	n/a	n/a
1989	2.66837	insig.	4.10497	insig.	0.77411	insig.	n/a	n/a	0.22947	insig.	2.08105	insig.	n/a	n/a
1990	2.50711	insig.	3.4292	insig.	0.68917	insig.	3.98576	insig.	0.99301	insig.	2.69666	insig.	n/a	n/a
1991	1.95631	insig.	3.13237	insig.	0.85063	insig.	2.74653	insig.	1.40172	insig.	1.05137	insig.	n/a	n/a
1992	2.02533	insig.	2.87534	insig.	0.65775	insig.	3.10537	insig.	0.11999	insig.	1.30389	insig.	n/a	n/a
1993	1.54933	insig.	2.2747	insig.	0.68522	insig.	3.54303	insig.	0.10547	insig.	0.75218	insig.	n/a	n/a
1994	2.23309	insig.	2.71196	insig.	0.9641	insig.	2.34468	insig.	0.10901	insig.	1.58156	insig.	n/a	n/a
1995	1.83462	insig.	2.67074	insig.	0.77377	insig.	3.50831	insig.	1.66713	insig.	0.72594	insig.	n/a	n/a
1996	3.24217	insig.	5.08127	10%	0.47194	insig.	1.62037	insig.	0.47524	insig.	0.91858	insig.	24.8984	1%
1997	1.78132	insig.	3.07961	insig.	0.44108	insig.	0.71689	insig.	0.13485	insig.	1.26449	insig.	2.22999	insig.
1998	1.31934	insig.	3.11014	insig.	0.57139	insig.	0.7832	insig.	0.10173	insig.	8.2708	1%	1.16837	insig.
1999	3.02494	insig.	3.0892	insig.	0.74336	insig.	0.4596	insig.	0.10293	insig.	2.54052	insig.	1.10071	insig.
2000	1.65064	insig.	3.35025	insig.	0.52703	insig.	0.27581	insig.	0.50546	insig.	4.34243	insig.	0.97698	insig.
2001	1.28567	insig.	3.09305	insig.	0.28889	insig.	0.30537	insig.	0.33944	insig.	2.2987	insig.	0.80282	insig.
2002	1.26644	insig.	3.33582	insig.	0.28606	insig.	0.32258	insig.	0.20432	insig.	2.6908	insig.	0.7771	insig.
2003	1.87498	insig.	2.74259	insig.	0.27488	insig.	0.27047	insig.	0.37699	insig.	2.20413	insig.	0.54417	insig.
2004	6.02052	5%	3.81937	insig.	2.11922	insig.	0.24957	insig.	0.49813	insig.	2.19342	insig.	0.67373	insig.
2005	13.6571	1%	2.84174	insig.	2.77	insig.	0.2689	insig.	4.96784	insig.	1.70962	insig.	0.81988	insig.
2006	5.31196	10%	4.66704	insig.	4.35491	insig.	0.37564	insig.	3.26758	insig.	2.8945	insig.	0.69035	insig.
2007	5.52167	10%	2.1713	insig.	16.9919	1%	4.52196	insig.	0.24835	insig.	61.1978	1%	3.06851	insig.

Obs.: Critical values for the QLR statistic with 15% trimming were obtained from Table 14.6 in Stock and Watson (2006, p. 568)

3. RESULTS OF CORRELATION TESTS OF CASE STUDY 3

List of variables:

- public = yearly number of articles on climate change in the *New York Times*, *Wall Street Journal*, *Washington Post* and *USA Today*
- congress = yearly number of climate-change-related outputs in the *Congressional Record*
- executive = yearly number of climate-change-related outputs in the *Federal Register*
- *anews* = yearly number of articles on climate change in the *Automotive News*
- bigthree = yearly sum of AFV patents by General Motors, Chrysler and Ford
- outsiders = yearly sum of AFV patents by other selected automakers
- afv = market share of alternative fuel vehicles in the US
- edv = market share of electric drive vehicles in the US

The correlation analysis was carried out using *Stata 12*.

Results for the whole period

```
. spearman public congress executive anews bigthree outsiders afv edv, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000							
	34							
congress	0.8601*	1.0000						
	34	34						
	0.0000							
executive	0.8716*	0.7314*	1.0000					
	34	34	34					
	0.0000	0.0000						
anews	0.4961	0.3251	0.0982	1.0000				
	25	25	25	25				
	0.0117	0.1129	0.6407					
bigthree	0.7510*	0.5670*	0.8649*	0.3900	1.0000			
	32	32	32	23	32			
	0.0000	0.0007	0.0000	0.0658				
outsiders	0.7526*	0.5711*	0.8892*	0.3866	0.9161*	1.0000		
	32	32	32	23	32	32		
	0.0000	0.0006	0.0000	0.0684	0.0000			
afv	0.8184*	0.8490*	0.8962*	0.1414	0.9142*	0.8848*	1.0000	
	18	18	18	18	17	17	18	
	0.0000	0.0000	0.0000	0.5758	0.0000	0.0000		
edv	0.7934*	0.5963	0.8330*	-0.3363	0.8531*	0.7832*	0.9066*	1.0000
	14	14	14	14	12	12	13	14
	0.0007	0.0244	0.0002	0.2398	0.0004	0.0026	0.0000	

Results for before 1987 (inclusive)

```
. spearman public congress executive anews bigthree outsiders afv edv if year<1988, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000							
	9							
congress	0.2827	1.0000						
	9	9						
	0.4611							
executive	0.5532	0.3590	1.0000					
	9	9	9					
	0.1223	0.3427						
anews	.	.	.	.				
	0	0	0	0				
	.	.	.					
bigthree	-0.5188	-0.3193	-0.5085	.	1.0000			
	9	9	9	0	9			
	0.1524	0.4022	0.1621	.				
outsiders	-0.6193	-0.7059	-0.1526	.	0.5500	1.0000		
	9	9	9	0	9	9		
	0.0753	0.0336	0.6952	.	0.1250			
afv	.	.	.	.	.	.	.	
	0	0	0	0	0	0	0	
	.	.	.	.	.	.		
edv	.	.	.	.	.	.	.	.
	0	0	0	0	0	0	0	0
	.	.	.	.	.	.	.	

Results for after 1987 (exclusive)

```
. spearman public congress executive anews bigthree outsiders afv edv if year>=1988, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000							
	25							
congress	0.6821*	1.0000						
	25	25						
	0.0002							
executive	0.6971*	0.3607	1.0000					
	25	25	25					
	0.0001	0.0765						
anews	0.4961	0.3251	0.0982	1.0000				
	25	25	25	25				
	0.0117	0.1129	0.6407					
bigthree	0.7213*	0.3551	0.9098*	0.3900	1.0000			
	23	23	23	23	23			
	0.0001	0.0964	0.0000	0.0658				
outsiders	0.6976*	0.3175	0.8994*	0.3866	0.9042*	1.0000		
	23	23	23	23	23	23		
	0.0002	0.1399	0.0000	0.0684	0.0000			
afv	0.8184*	0.8490*	0.8962*	0.1414	0.9142*	0.8848*	1.0000	
	18	18	18	18	17	17	18	
	0.0000	0.0000	0.0000	0.5758	0.0000	0.0000		
edv	0.7934*	0.5963	0.8330*	-0.3363	0.8531*	0.7832*	0.9066*	1.0000
	14	14	14	14	12	12	13	14
	0.0007	0.0244	0.0002	0.2398	0.0004	0.0026	0.0000	

Results for before 1996 (inclusive)

```
. spearman public congress executive anews bigthree outsiders afv edv if year<1997, stats(rho obs p) st(0.01) pw

  Key
  rho
  Number of obs
  Sig. level

             |   public congress execut~e    anews bigthree outsid~s      afv      edv
-------------+--------------------------------------------------------------------------
      public |   1.0000
             |       18
             |
             |
    congress |   0.9039*  1.0000
             |       18       18
             |   0.0000
             |
   executive |   0.7346*  0.6946*  1.0000
             |       18       18       18
             |   0.0005   0.0014
             |
       anews |   0.6778   0.7197  -0.3598   1.0000
             |        9        9        9        9
             |   0.0448   0.0288   0.3415
             |
    bigthree |   0.0702   0.0692   0.3650  -0.2427   1.0000
             |       18       18       18        9       18
             |   0.7819   0.7849   0.1363   0.5292
             |
   outsiders |   0.1373   0.0961   0.5657  -0.3849   0.6821*  1.0000
             |       18       18       18        9       18       18
             |   0.5869   0.7045   0.0144   0.3063   0.0018
             |
         afv |   0.5000   0.5000  -1.0000   0.5000   0.5000   0.5000   1.0000
             |        3        3        3        3        3        3        3
             |   0.6667   0.6667   1.0000   0.6667   0.6667   0.6667
             |
         edv |        .        .        .        .        .        .        .        .
             |        0        0        0        0        0        0        0        0
             |        .        .        .        .        .        .        .
             |
```

Results for after 1996 (exclusive)

```
. spearman public congress executive anews bigthree outsiders afv edv if year>=1997, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000							
	16							
congress	0.7316*	1.0000						
	16	16						
	0.0013							
executive	0.6353*	0.6696*	1.0000					
	16	16	16					
	0.0082	0.0045						
anews	0.0765	-0.0767	-0.5059	1.0000				
	16	16	16	16				
	0.7783	0.7777	0.0456					
bigthree	0.6923*	0.7528*	0.7934*	-0.2308	1.0000			
	14	14	14	14	14			
	0.0061	0.0019	0.0007	0.4273				
outsiders	0.7011*	0.7307*	0.6967*	0.0198	0.7407*	1.0000		
	14	14	14	14	14	14		
	0.0052	0.0030	0.0056	0.9465	0.0024			
afv	0.6893*	0.7419*	0.8643*	-0.3679	0.8505*	0.8198*	1.0000	
	15	15	15	15	14	14	15	
	0.0045	0.0015	0.0000	0.1773	0.0001	0.0003		
edv	0.7934*	0.5963	0.8330*	-0.3363	0.8531*	0.7832*	0.9066*	1.0000
	14	14	14	14	12	12	13	14
	0.0007	0.0244	0.0002	0.2398	0.0004	0.0026	0.0000	

Results for before 2005 (inclusive)

```
. spearman public congress executive anews bigthree outsiders afv edv if year<=2005, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000							
	27							
congress	0.8066*	1.0000						
	27	27						
	0.0000							
executive	0.7702*	0.6176*	1.0000					
	27	27	27					
	0.0000	0.0006						
anews	0.8673*	0.3476	0.2851	1.0000				
	18	18	18	18				
	0.0000	0.1575	0.2514					
bigthree	0.5920*	0.3459	0.7756*	0.4171	1.0000			
	27	27	27	18	27			
	0.0011	0.0772	0.0000	0.0850				
outsiders	0.5978*	0.3752	0.8331*	0.2612	0.8797*	1.0000		
	27	27	27	18	27	27		
	0.0010	0.0538	0.0000	0.2951	0.0000			
afv	0.5874	0.6831	0.6620	0.3636	0.7762*	0.8881*	1.0000	
	12	12	12	12	12	12	12	
	0.0446	0.0143	0.0190	0.2453	0.0030	0.0001		
edv	0.2500	0.0360	0.0357	0.0000	0.3214	0.8929*	0.7143	1.0000
	7	7	7	7	7	7	7	7
	0.5887	0.9389	0.9394	1.0000	0.4821	0.0068	0.0713	

Results for after 2005 (exclusive)

```
. spearman public congress executive anews bigthree outsiders afv edv if year>=2005, stats(rho obs p) st(0.01) pw

  Key

   rho
   Number of obs
   Sig. level

              |  public congress execut~e    anews bigthree outsid~s      afv      edv
--------------+------------------------------------------------------------------------
       public |  1.0000
              |       8
              |
              |
     congress |  0.6190   1.0000
              |       8        8
              |  0.1017
              |
    executive | -0.0476   0.0476   1.0000
              |       8        8        8
              |  0.9108   0.9108
              |
        anews |  0.4524   0.5476  -0.6905   1.0000
              |       8        8        8        8
              |  0.2604   0.1600   0.0580
              |
     bigthree |  0.3714   0.5429   0.9429* -0.4286   1.0000
              |       6        6        6        6        6
              |  0.4685   0.2657   0.0048   0.3965
              |
    outsiders |  0.3143  -0.1429  -0.6571   0.8286  -0.6000   1.0000
              |       6        6        6        6        6        6
              |  0.5441   0.7872   0.1562   0.0416   0.2080
              |
          afv | -0.0357   0.2500   0.9286* -0.5714   0.8286  -0.5429   1.0000
              |       7        7        7        7        6        6        7
              |  0.9394   0.5887   0.0025   0.1802   0.0416   0.2657
              |
          edv |  0.3810   0.0476   0.7381  -0.5714   0.8857  -0.6000   0.6786   1.0000
              |       8        8        8        8        6        6        7        8
              |  0.3518   0.9108   0.0366   0.1390   0.0188   0.2080   0.0938
              |
```

Results for second sub-period [1988-1996]

```
. spearman public congress executive anews bigthree outsiders afv edv if year>=1988 & year<1997, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000							
	9							
congress	0.9667*	1.0000						
	9	9						
	0.0000							
executive	-0.7000	-0.6833	1.0000					
	9	9	9					
	0.0358	0.0424						
anews	0.6778	0.7197	-0.3598	1.0000				
	9	9	9	9				
	0.0448	0.0288	0.3415					
bigthree	-0.6000	-0.6167	0.4833	-0.2427	1.0000			
	9	9	9	9	9			
	0.0876	0.0769	0.1875	0.5292				
outsiders	-0.5833	-0.5667	0.8167*	-0.3849	0.6000	1.0000		
	9	9	9	9	9	9		
	0.0992	0.1116	0.0072	0.3063	0.0876			
afv	0.5000	0.5000	-1.0000	0.5000	0.5000	0.5000	1.0000	
	3	3	3	3	3	3	3	
	0.6667	0.6667	1.0000	0.6667	0.6667	0.6667		
edv	.	.	.	.	.	.	.	.
	0	0	0	0	0	0	0	0
	.	.	.	.	.	.	.	

Results for third sub-period [1997-2005]

```
. spearman public congress executive anews bigthree outsiders afv edv if year>=1997 & year<2005, stats(rho obs p) st(0.01) pw
```

Key
rho
Number of obs
Sig. level

	public	congress	execut~e	anews	bigthree	outsid~s	afv	edv
public	1.0000 8							
congress	-0.1220 8 0.7735	1.0000 8						
executive	-0.5476 8 0.1600	0.1220 8 0.7735	1.0000 8					
anews	0.6190 8 0.1017	-0.3416 8 0.4076	-0.6667 8 0.0710	1.0000 8				
bigthree	0.0000 8 1.0000	0.2684 8 0.5204	0.1190 8 0.7789	-0.4286 8 0.2894	1.0000 8			
outsiders	0.0000 8 1.0000	0.3172 8 0.4440	0.0476 8 0.9108	-0.5952 8 0.1195	0.5476 8 0.1600	1.0000 8		
afv	0.0000 8 1.0000	0.1952 8 0.6432	0.2857 8 0.4927	-0.5238 8 0.1827	0.5714 8 0.1390	0.8810* 8 0.0039	1.0000 8	
edv	0.0286 6 0.9572	-0.3189 6 0.5379	-0.5429 6 0.2657	0.0857 6 0.8717	0.2571 6 0.6228	0.8286 6 0.0416	0.8286 6 0.0416	1.0000 6