The development of three new infrastructure sectors in a hierarchical market economy

Tomás Osvaldo Saieg Páez

Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Sussex

November 2016

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.

Signed:……………………………………………………………………………………………..……………..

Tomás Osvaldo Saieg Páez

UNIVERSITY OF SUSSEX

Tomás Osvaldo Saieg Páez, DPhil in Science and Technology Policy Studies

The development of three new infrastructure sectors in a hierarchical market economy

Summary

To make the most of emergent techno-economic innovations, countries around the world must constantly upgrade their physical infrastructure and infrastructure systems – more than ever now that the world is facing growing environmental constraints. Public policies that foster the transformation of established infrastructure sectors, and encourage the development of new ones, can help to speed up and direct these structural changes. But to be effective, these policies must take into account how the process of development of new sectors varies among different infrastructure sectors, how it varies with respect to other kinds of sector, and how it varies in different institutional contexts. In this work, I show how three new infrastructure sectors developed in Chile, a 'Hierarchical Market Economy' characterised by the dominance of diversified business groups and subsidiaries of multinational enterprises, a segmented labour market, and a low-skills equilibrium. These three sectors are the ones that first started to build wind farms, solar PV systems, and anaerobic digesters in the country, and in the study I characterize three aspects of their development process: a) the economic changes that turned these new (to the country) kinds of infrastructure facilities into attractive entrepreneurial opportunities; b) the economic agents that discovered these opportunities and developed them into viable investment projects, and those that sponsored and procured finance to build these projects; and c) the means by which these economic agents became capable of undertaking the relatively novel activities that their entrepreneurial initiative demanded. The resulting rich description of new sectoral development processes in Hierarchical Market Economies helps to understand what makes these processes vary inter-sectorally, cross-sectorally, and cross-nationally.

Acknowledgements

I would first like to thank Tommaso Ciarli, my main supervisor. He has been kind and generous to me since the beginning, and his guidance and feedback have been fundamental to this work. I would also like to thank Ed Steinmueller, who has also been kind and generous, and whose overseeing role prevented me from following many blind alleys. And warm thanks go as well to José Porcile from ECLAC, whom generously welcomed me there during my year of fieldwork.

I am also deeply thankful to my friends from Brighton, whose warmth and kindness made these happy years. Thanks to Alba, Ana Paula, Antonio, Claudia, Diego, Edwin, Erika, Jenny, José, Mar, Nadia, Paloma, Patricio, Pavel, Raul, Rocío, Veronica, Yusuf and my other (real and honorary) Latin American friends, who gave a homely taste to the whole experience. Thanks to Cian, Jake, Olivia and Sabine for the many breakfasts we shared together after an early morning swim. And thanks to Eva, Jonas, Marco, Mattia, Stace and others from the beach volleyball gang, with whom we were not far from winning the summer league.

Thanks go as well to many other friends from SPRU and Economics. These include Adrian, Antonia, Bernardo, Blanche, Caetano, Chantal, Claire, Emily, Frederique, Jorge, Matt, Mimi, Phil, Rob, Ruth, Sandra and Sungjoo, among many others. Coming from many different countries, sharing experiences with them over the years was not just pleasant but also a great way to learn about how things are in other places.

Thanks to the *Becas Chile* scholarship program, for providing me the funding and therefore the opportunity to pursue my PhD project in the UK.

And thanks too to family and friends from Chile, whom I've missed a lot.

To my friends from Brighton

Table of Contents

List of Figures

List of Tables

Abbreviations

CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CME	Coordinated Market Economy
CNE	Comisión Nacional de Energía
DRAM	Distributed Random Access Memory
DUFC	Domestic Under Foreign Control
EG	Electricity Generation
EGP	Enel Green Power
EIA	Environmental Impact Assessment
FDI	Foreign Direct Investment
FSCI	Foreign Skills Content Indicators
GEF	Global Environment Facility
GVC	Global Value Chain
HME	Hierarchical Market Economy
ICT	Information and Communication Technology
ILC	Industry Life Cycle
IS	Innovation System
ISI	Import Substituting Industrialization
ISIC	International Standard Industrial Classification
LCOE	Levelized Cost of Electricity
LME	Liberal Market Economy
ME	Market Economy
MNC	Multi National Corporation
MNE	Multi National Enterprise
NCRE	Non-Conventional Renewable Energy

NIS	National Innovation System
NME	Network Market Economy
NSI	National System of Innovation
PDD	Project Design Document
PPA	Power Purchase Agreement
RCA	Revealed Comparative Advantage
REP	Rural Electrification Program
SEIA	Servicio de Evaluación de Impacto Ambiental
SSI	Sectoral System of Innovation
TFP	Total Factor Productivity
UNDP	United Nations Development Program
USSR	Union of Soviet Socialist Republics
WWI	World War I
WWII	World War II
WWT	Waste and Wastewater Treatment

Chapter 1
Introduction

History doesn't repeat itself, but it does rhyme

Mark Twain?

1.1. Long Waves

Buddhism and Hinduism, and several American cultures such as the Q'ero Indians of Peru, conceive of time as a cyclical phenomenon: analogous eras endlessly repeat themselves, circumnavigating the wheel of time. Christianity, on the other hand, thinks of time as linear: it all started with the Genesis, and it will all finish with the Armageddon. But time can also be imagined as something that combines the circular and the linear, forming a spiral: this is what Mark Twain did when he allegedly said that history does not repeat itself, but it does often rhyme.

Like Mark Twain's (probably apocryphal) quote about history, Carlota Perez's theory of great surges (Perez, 2003, 1983) is a theory of the evolution of the capitalist economy that views the development of this system of socio-economic organization as a spiral process, one that that began with the British Industrial Revolution and continues to this day. In her view, the long waves in key macroeconomic variables first identified by Nikolai Kondratiev in the 1920s (Kondratiev, 1925), and whose existence was later confirmed using modern methods (Korotayev and Tsirel, 2010), can be explained as the result of the cyclical misalignment-realignment of the techno-economic and socio-institutional spheres of the capitalist world economy. The profit motive drives techno-economic innovation, which does not advance haphazardly but rather follows certain technological trajectories (Dosi, 1982a), and which subjects the economy to disruptive waves of creative destruction (Schumpeter, 1942). These waves of creative destruction generate a downswing of rising social and institutional tensions, but also enable the breeding of new and more productive technological trajectories. Over time, the socio-institutional framework becomes more and more ill-adapted to the emergent techno-economic regime. This leads to a social, political, and economic crisis which can only be overcome when the leaders of these three realms of activity manage to design, agree on, and implement a socio-institutional framework that is more fitting to the new technological regime. Success in this endeavour leads to the unleashing of the life-improving potential of the new modes of production, i.e. to an upswing which is a golden age of widespread social and economic progress (Perez, 2013). But, as time goes by, the productivity-enhancing potential of the new technologies is exhausted, and innovation starts to focus on new technological trajectories. This, again, subjects the economy to disruptive waves of creative destruction, and the cycle – which lasts about 50 years – repeats itself.

According to the theory, each great surge can be characterised – among other things – by the intensive use of one or a few key production inputs or factors which become cheap and pervasive, and by the organisation of investment into a branched pattern where one can distinguish between carrier, motive, and induced branches. The carrier branches are the sectors that make the most intensive use of the key factors, and that drive all of the rest. The motive branches are those that assist in making the key factors inexpensive and widely available. And the induced branches, which 'multiply in bandwagon fashion' only after the upswing is unleashed through appropriate socio-institutional upgrade, are those that are made possible by and complement the carrier branches, often re-absorbing the labour that is displaced by the radical increases in productivity that these last experience (Perez, 1983).

Perez and others argue that there have been five great surges. On the first of these, 'The Age of Cotton, Iron and Water Power,' the key production factors were iron, raw cotton, and coal, and the carrier branches were cotton products and iron products. On the second, 'The Age of Iron Railways, Steam Power and Mechanization,' the main factors were again iron and coal, and the carrier branches railways and railway equipment, steam engines, machine tools, and the alkali industry. On the third wave, 'The Age of Steel, Heavy Engineering, and Electrification,' the most important factors were steel, copper, and metal alloys, and the carrier branches were electrical equipment, heavy engineering, heavy chemicals, and steel products. The fourth wave, 'The Age of Oil, Automobiles, Motorization and Mass Production,' was one where oil, gas and synthetic materials became the key factors, and automobiles, trucks, tractors, tanks, diesel engines, aircraft and refineries the carrier branches. And on the fifth wave – 'The Age of Information and Communication Technology,' which is the one which we are still living in – the key factors are integrated circuits, and the carrier branches are computers, software, telecommunication equipment, and biotechnology (Freeman and Louçã, 2002; Perez, 2010).

Alongside specific key factors and a branched pattern of investment, the great surges have historically been accompanied by the expansive growth of particular – often novel, but not necessarily – infrastructure systems, which shape and extend the market boundaries for all the other sectors (Perez, 2010). In the case of the first Kondratiev, the main components of the infrastructure system were the canals, turnpike roads, and sailing ships network which – among other things – enabled the transport of British cotton manufactures from the industrial centres of the north to the commercial centres of the south and the wider world. In the case of the second, the main components of the system were the iron railways and steam ships that enabled goods and people to move around with previously unknown speed and affordability, and the telegraphs that enabled almost instant communication among faraway places. In the third great surge, steel railways and steel ships took the place of iron railways and steam ships, and telephones replaced the telegraph, further widening the speed and affordability of transport, travel and communication. And in the fourth, it was the turn of radio transmission systems, motorways, airports and airlines to do just the same (Freeman and Louçã, 2002).

1.2. The New Infrastructure

And what about the fifth and current great surge, The Age of Information and Communication Technology (ICT)? What are the main components of its defining infrastructure system? Is this system already in place, or is it yet to be installed?

Certainly, some of the most important components of the system are already in place: these are the cable, fiber optic, radio, and satellite communication networks which, together with routing equipment, servers and other such hardware, and information and communications software, enable the Internet, which is the main infrastructure innovation of the current Kondratiev (Freeman and Louçã, 2002; Perez, 2010). There is, however, good reason to believe that the upgrade of the world's infrastructure systems can and will advance far beyond what it currently has: although ICT is now widespread, there are still many places in the world with deficient or no connectivity (Baller et al., 2016). But perhaps more importantly, one can make the case that ICT infrastructure is one of several components of a broader infrastructure system which needs to be put in place if we are to bring the current surge to a virtuous conclusion.

Such is part of the case that Perez makes in (Perez, 2013). In this article, she argues that, since the 2000 dotcom crisis and through the 2008 global recession, we have been living in an extended version of the mid-point of the current great surge, a time when the downswing of accumulating social and institutional tensions brought about by the new ICT techno-economic regime has turned into a crisis – a crisis which will not be overcome and turn into an upswing of prosperity until measures are taken to overhaul the socio-institutional framework. In her article, she recognizes the need to expand the ICT infrastructure, but then adds that further infrastructure system investments are needed in order to steer the Kondratiev upswing in a direction which is compatible with the well-known environmental pressures that the world is currently experiencing (IPCC, 2015), pressures that constitute one of the truly novel features of the current great surge.

The list of further needed infrastructure system investments is long and can only be speculative, for there are many different visions of how a truly sustainable socio-economic system may look like. But one thing that is certain is that, if any such green future vision is to be achieved, the energy provision infrastructure of the world will need to transition from being based on fossil fuels to being based on renewable energies – something which is already happening (IEA, 2015), and which is parallel to other energy system transitions that have taken place in the past (Geels, 2012). Wind farms, solar PV systems, nuclear, biomass, biogas and hydroelectric power plants, and probably other new electricity generation technologies which are still not as mature as these will all play a role in this transition, replacing the dirty fossil-fuel-based technologies. But the energy system overhaul will certainly need to go beyond this, as it's already doing: energy storage, demand management, resilient transmission, and adaptable distribution infrastructure also needs to diffuse or be upgraded in order to achieve a low-carbon energy system. All of this new energy infrastructure will need to be closely integrated with the ICT infrastructure to form flexible smart grids (IEA, 2011).

Greening the world's energy infrastructure is one of the key challenges ahead, but it is by no means the only one. There are several other areas where infrastructure systems need to be upgraded or created anew in order to make sure that the (hopefully) forthcoming Kondratiev upswing leads to a sustainable future. As more and more people move to cities – the 3.9 billion people that lived in cities by 2014 was expected to rise to 6.4 billion by 2050 (IOM, 2015) –, water provision and sanitation infrastructure systems will become stressed and will require new investment (UN-WATER, 2014). The growth of city living will also put pressure on urban transport systems, which besides accommodating more people will also need to become greener; this will likely require infrastructure investments in roads, tram, subways, and perhaps new forms of urban transport that we don't yet fully envisage (Van Audenhove et al., 2014). Similar challenges need to take place in several other infrastructure systems for this green vision to become a reality (Moss and Marvin, 2016; OECD, 2007, 2006).

1.3. Place and Context

Despite globalisation, neither the current nor the past great surges have affected all parts of the world equally: each new technological revolution has been centred in one or a few places and has had effects in other places which have been belated and of various different natures. As is well known, the British Industrial Revolution – the first of the great surges – led to the widespread mechanisation of the British textiles industry, but it also led to the crushing of its non-mechanized but massive Indian counterpart (Hobsbawm, 1999). A great number of economies have never really had their own cotton spinning, machine tools, heavy engineering, automobiles, or telecommunications equipment industries, but have nevertheless been affected by the five Kondratievs because of their trade and other relations with the countries in which these carrier-branch sectors have developed. Sometimes, as with Russia, economies have been on the peripheries of the first few great surges but have industrialised later, developing their own versions of the corresponding carrier and motive branch sectors and becoming centres of latter surges (Gerschenkron, 1962). In other occasions, such as with Korea, countries have caught up with the new technological revolutions by specialising in motive-branch sectors as a platform to move, later on, to the carrier-branch ones (Amsden, 1989; Kim, 1997). Great surges are global phenomena, but their global effects are uneven.

The above is no doubt as true for the development of each technological revolution's leading sectors as it is for the installation of the infrastructure systems that are associated with them. Few if any places had a network of canals, turnpike roads and sailing ships – the main components of the first Kondratiev's infrastructure system – as broad as Britain's, the centre of the first great surge. Not all countries built railways or telegraphs. Telephones spread widely but not exhaustively, and their diffusion took a long time. Though roads exist everywhere, high-speed motorway networks don't, and where they exist they are not always of the same quality: not every country has an *Autobahn* as extensive and well maintained as Germany's. And as we have seen, ICT infrastructure systems are widespread but not all-encompassing, and they have huge quality differences. The diffusion of new infrastructure systems is thus not an inevitable by-product of great surges that can be taken for granted, but rather something that may or may not happen depending on various factors.

One key difference between the centers of the great surges and the rest of the world is that, whereas in the former infrastructure sector innovation is sometimes new-to-the-world, in the latter it is usually new-to-the-country: the Internet, to take an example from the current surge, was an experimental US computers communication network that did not exist anywhere else before spreading through the rest of the world (Leiner et al., 2009); and railway networks, to take another, had been tried and tested in Europe before they arrived in South America, where they never became as extensive. This new-to-the-country rather than new-to-the-world character of the process by which new infrastructure sectors develop in the less techno-economically advanced countries is one key reason why knowledge about it must take into account the place and the context where the process unfolds.

1.4. What Comes Next

The goal of this study is to understand how new infrastructure sectors develop in a certain kind of context of which the country I have chosen to look at (Chile) is to some extent representative. Whether the experience of any country can be compared with that of another, no doubt, is always open to debate. But, as we will see in some more detail in Chapter 3, there a number of characteristics of this country that are directly relevant to our subject matter, and that place it side by side with various other countries in a number of continents but especially in South America: the widespread presence of foreign multinationals, the organization of the largest domestic firms in diversified business groups, the prevalence of segmented labor markets, and the comparatively low skills of the majority of the working population (Schneider, 2013). The many countries that share these traits are the ones for which the lessons to be drawn from this study will be most relevant.

One more goal of this study, which is also one of its main contributions, is to approach its topic from a broad perspective, one that looks at new infrastructure sector development processes as they happen at various levels: the world, the country, the sector, and the firm. In this introduction, we have set the ball rolling by noting how infrastructure systems tend to change periodically and following the logic of Perez's theory of great surges, which is a theory of socio-techno-economic structural change at the world level (Perez, 2010, 2003, 1983). As we move through the empirical chapters – where we will be analysing how the Wind, Solar, and Anaerobic Digestion infrastructure sectors emerged in Chile –, we will engage with the matter at these different levels, loosely following a logic that goes from the broader to the more focused. Thus first, in Chapter 4, we will try to understand how building these three kinds of infrastructure facility became attractive entrepreneurial opportunities for the economic agents that developed them and invested in them. Then, in Chapter 5, we inquire about the kinds of economic agent that pursued these opportunities, about the way in which they did so, and about why it was them and not others that fulfilled this entrepreneurial function. And in Chapter 6, we will investigate how the capabilities to pursue these entrepreneurial opportunities were developed within the economy, and the degree to which these capabilities relied on the skills of foreigners.

But before these three empirical chapters, we will need to develop the conceptual apparatus that will inform and guide the inquiry, a task that we will tackle in the next two chapters. In Chapter 2, the first of these, we will review three related bodies of literature that are directly relevant to our topic and to which this study aims to make a contribution: the literature on structural change, that on capabilities and development, and the one about sectoral organisation and evolution. This chapter will serve to place the study in context and to motivate it from an academic point of view. And, in Chapter 3, we will develop a theoretical framework that will unite several aspects of these three bodies of literature into a coherent whole that we can use for our purposes. There, we will also see what are the formal research questions that we will try to answer, and what is the research design that we will use to do so.

The study will finish with a discussion and conclusions chapter. There, we will take a step back and engage in further reflections about the results that we'll go through in Chapters 4, 5 and 6, draw the policy implications of these results and reflections, discuss this work's methodological limitations, and highlight what have been its main academic contributions.

Chapter 2

Literature Review

In this chapter, we will review three bodies of literature that offer complementary insights about the question of how new sectors develop *in general*. This literature will motivate the study and serve as a foundation to build a better understanding of how new *infrastructure* sectors develop *in economies like Chile's*, a kind of economy which we will properly characterise in Chapter 3. The literature on structural change, the first to be reviewed, looks at new sector development processes in the aggregate, and helps to understand what the main general forces that drive them are. The literature on capabilities and development, the second that we will go through, is composed of studies that focus on the microeconomic foundations of these processes: the capabilities that economic agents need to develop in order to undertake new activities. The literature on sectoral organisation and evolution, the third and last, shows how the emergence of new sectors is always part of broader sectoral transformation processes, and offers various insights into their dynamics.

2.1. Structural Change

Robert Solow's well-known economic growth theory treats the economy as one big and homogeneous system where economic output (Y) comes from combining labour (L) and capital (K), so that Y = f(K,L) (Solow, 1956). The outlook of the literature on structural change differs from this and related approaches in that it recognises the heterogeneity of sectors, places importance on it, and seeks to understand it. In this literature, the economy is divided into sectors with the goal of understanding why and how, as time goes by, some sectors grow while others shrink – i.e. why the structure of the economy changes. Sometimes, the sectors under study are new in some important sense, and in those cases, the issue is not so much their growth as their initial development. But more often than not, the focus is on the growth or de-growth of sectors that already exist. Given the breadth of its central theme, the literature is enormously diverse (Silva and Teixeira, 2008). We, however, don't need to cover it all: what is relevant for our purposes is a review that enables us to see what the main forces purported to cause structural change are.

Following Schumpeter's groundbreaking analyses, most scholars now agree that one of the central forces behind structural change is innovation, defined by him as the introduction of new goods, new qualities of goods, new services or new production methods; the opening of new markets or new sources of raw materials; or the carrying out of better means of economic organization (Schumpeter, 1942, 1912). The mechanism by which innovation can cause structural change is simple: typically, innovation increases productivity, either by reducing costs or by increasing output value. The rate of innovation, however, is not the same for all sectors. Sectors with higher rates of innovation will thus become more productive relative to those with lesser rates, and this will lead to a redistribution of economic resources towards them. Thus, as the invention and, most importantly, diffusion of personal computers and the Internet led people to get jobs as computer programmers, innovation has lead in the past and will lead in the future to analogous resource redistributions, even though not necessarily always of the labor 'resource' (Fagerberg, 2000; Salter, 1960). Although innovation, as defined by Schumpeter, is a very broad notion, many studies deem *technological* innovation, or more broadly technical change, to be the central force. Thus for instance Kuznets, reflecting on his years of study about the matter, writes that 'rapid changes in production structure are inevitable – given the differential impact of technological innovations on the several production sectors, …'[1] (Kuznets, 1973, p. 5). In (Kuznets, 1973; Kuznets and Murphy, 1966), Kuznets goes further to note that overall high performance in economic growth is accounted for by average rates of growth across many sectors and exceptional rates of growth in a few sectors

Long-wave theory (Freeman and Louçã, 2002; Perez, 2010), as we saw in the previous chapter, suggests innovation tends to take place in spurts of related developments that follow what Giovani Dosi famously called technological trajectories (Dosi, 1982a). This would seemingly explain why innovation, as we saw above, has a tendency to cluster in some sectors – those at the centre of the rising technological trajectories. One reading of long wave theory, stating that one of its implications is that innovation should *periodically* cluster in some given phase of the waves, has been ably criticised by Silverberg and others, who question the methodologies that defendants of this view have used to hold it (Silverberg and Verspagen, 2003). This criticism, however, does not apply to the *sectoral* clustering that would explain why innovation can become a significant driver of structural change. As with the cluster of related innovations in agricultural practices, cotton preparation, spinning, weaving and finishing that took place through the British Industrial Revolution, and that was fundamental to making this country's textile industry the carrier

[1] And some other forces that we will get to later.

branch of this first great surge; technological development tends to be a distributed but coherent process.

Theories of structural change that are largely based on historical analyses, such as long-wave theory, are not the only ones that recognise technical change as a key force: most formal models of the process also recognise the importance of this central driver. In these formal models, the economy is typically divided into two or more sectors, and their growth or de-growth trajectory is modelled using systems of equations, agent-based models, or other such representations. Many of the most prominent among these formal representations feature either technological innovations or their main purported effect – an increase in the productivity of the sectors where the innovations take place – as a central force (Krüger, 2008). This includes three-sector growth models such as that in (Echevarria, 1997), where the broadly defined agricultural and extractive, manufacturing, and services sectors differ in their rates of technical progress and hence grow at different rates; multi-sector endogenous growth models such as that in (Aghion and Howitt, 1990), where the economy is modelled as if it produced one undifferentiated final good but using inputs from many intermediate sectors that contribute to the production of the final good according to their differing productivities; and evolutionary models such as that in (Saviotti and Pyka, 2004), which is one of the few that does not start by assuming a fixed number of sectors that may grow or de-grow, but rather allows for the emergence of wholly new sectors spawning from radical innovations.

Great surges, as we also saw, do not affect equally all parts of the world: as the Industrial Revolution had its origins in England, other revolutions have had their origins in certain techno-economically advanced economies, but have *diffused* only gradually and partially, and sometimes not at all, to 'peripheral' (Prebisch, 1950; Wallerstein, 1979) or 'less complex' (Hidalgo and Hausmann, 2009) economies. A long-standing preoccupation of development scholars and practitioners has been the question of how these lower-complexity economies can catch-up with their advanced counterparts (Gerschenkron, 1962; Prebisch, 1950). Perez and Soete (1988) develop the argument that catching-up crucially depends on timing: as a technological revolution unfolds, the scientific and technological knowledge, locational advantages, fixed investments, and relevant skills and experience required to catch-up with it vary; because of this, catch-up is far easier at certain points in the unfolding revolution, which they call 'windows of opportunity'. One can better see their argument by reflecting on how several East Asian economies caught up with 'The Age of Information and Telecommunications': countries such as Korea (Kim, 1997) and Taiwan (Mathews, 1997) successfully entered into ICT manufacturing once the ICT revolution was mature; in this phase, much of the required knowledge had been codified (Johnson et al., 2002) and was thus easier to acquire; also, established leaders from the advanced countries were concentrated in advanced innovations such as personal computers, and were thus willing to procure components that were becoming commoditized, such as DRAM memories, from catching-up countries. On a related vein, Verspagen (1991) explains how catch-up crucially depends on the capacity of the peripheral economies to absorb new technical knowledge, which Cohen and Levinthal (1990) have famously called 'absorptive capacity'.

The contrast of the ways in which innovation may drive structural change in advanced vs. lower-complexity countries[2] points to a deeper fact about this important economic process: although the forces that drive it may originate within the economy, they can also be – and very often are – external. History provides many examples of structural change processes being unleashed by external forces. One clear example is the effect that events from World War I (WWI) to World War II (WWII) had on many Latin American economies. As one scholar put it, 'World War I, the Great Depression of the Thirties and World War II induced pronounced spurts of [Import Substituting Industrialization (ISI)] in most larger Latin American countries … The interruption of shipping and the decline of non-military production in Europe and the United States during World War I created severe shortages of imported manufactured goods in Latin America, raised relative prices of such goods, and increased profitability of ISI investment … The depression of the Thirties resulted in renewed shortages of imported goods. The fall of foreign exchange receipts from exports forced most countries of the region drastically to curtail imports. The decline resulted at first in increased use of productive capacity which had been underutilised in the Twenties, and later in the creation of new industrial capacity … [and] World War II had a stimulating effect on ISI industries: shortages of foreign manufactured goods led to full utilization of industrial capacity' (Baer, 1972, p. 4). As Baer shows, the detrimental effects on international trade of events in this period led to severe import restrictions in many Latin

[2] Throughout the thesis, we will favor the phrase 'lower-complexity' over the more common 'developing', 'emerging', or 'lower-income' economies/countries. Although this is a significant departure from common practice, it has several advantages over other terms. 'Developing', 'emerging' and 'catching-up', if used without care, may give 'the false impression that middle-income [and, for that matter, lower-income] countries are in flux and unformed and have not already consolidated enduring economic institutions' (Schneider, 2013, p. 9). 'Developing', moreover, is a subjective classifier which I find condescending. 'Lower-income' has the advantage of being objective, but also the disadvantage that countries of similar income levels can have widely differing levels of techno-economic sophistication (e.g. petro states vs. states at similar income levels). Dividing countries in terms of their economic complexity (at the top of the scale, the 'techno-economically advanced' or simply the 'advanced' countries, and below them the 'lower-complexity countries') avoids all of these pitfalls.

American countries, which relied on imports from the advanced economies for many of their activities and much of their consumption. Analyses of the period show that, to a considerable extent, these external influences planted the seeds of ISI in Latin America, a development trajectory which was later prolonged and fostered by policies based on a theory of economic development that saw technological dependency as a limitation to sovereignty and to development prospects (Bruton, 1998; Hirschman, 1968; Perez, 1996; Prebisch, 1950).

Albert Hirschman once noted how one of the reasons why ISI took off was that, in the more affluent years when imports were not so severely restricted, these created appetites for new products that were previously unknown, appetites that would not have been felt as scarcities once imports were restricted had they not been fostered by these same imports in the first place (Hirschman, 1958). However, imports leading to the development of new appetites, and from there to new markets, is just one instance of a much more general structural change driver: changes in consumption preferences. These changes may owe their origins to imports, but also to other factors. For example, at least since Ernst Engel observed that, as income rises, the proportion spent on food falls (Engel, 1857), economists have known that different goods and services have different income elasticities, or in other terms that consumer preferences are 'non-homothetic' (Blundell, 1988). From this, it follows that, as income-per-capita grows, consumption will not grow in equal proportions in all sectors: no matter how much the economy grows, people will only buy so much butter or so many shoes. These changes in consumption preferences are a powerful force that, by releasing income that people can spend in buying the produce of sectors where demand is not saturated, can cause significant changes in economic structure. Many formal structural change models place non-proportional growth in aggregate demand due to changing consumption preferences as a central driving force, on a par with technical change (Metcalfe et al., 2006; Montobbio, 2002) or as an even more significant factor (Pasinetti, 1983).

Besides technical change and changes in consumption preferences, one more central and – as they all are – interrelated structural change force are fluctuating resource availabilities. In Lewis's dual-sector model, widely regarded as a foundational contribution to development economics, it is scarcity of land – a natural resource – brought about by growing population – the labor 'resource' – that leads to diminishing productivity per agricultural worker, which creates the surplus of labor that enables modern sectors to grow (Lewis, 1954). The historian Fernand Braudel, in his magnum opus *Civilisation and Capitalism*, shows how the availability of energy was a key economic development problem faced by most civilisations (Braudel, 1967): once new energy sources became available, previously unfeasible energy-intensive activities and, with them, energy-intensive sectors could develop. Moreover, as we have seen, each new techno-economic paradigm has been underpinned by the widespread availability of resources which had previously been scarce: cotton, iron and coal in the first great surge; iron and coal in the second; steel, copper and metal alloys in the third; oil, gas and synthetic materials in the fourth; and integrated circuits in the fifth (Freeman and Louçã, 2002; Perez, 2010). The expansion in the availability of previously scarce resources – when these are natural resources, often sudden, and often triggered by technological innovations – and the contraction in the availability of others hitherto widely available have been historically powerful structural change forces.

On top of the aforementioned structural change drivers, history also provides numerous examples of deep changes in the economic structure being driven by shifts in policies or, more broadly, institutions. As mentioned, it is socio-institutional catching-up that, in great surge theory, enables the upswings that lead to golden eras, eras where the induced branches of the techno-economic paradigms can develop and absorb the labour displaced by technological innovations in the carrier and motive branches (Perez, 2013, 2010). The mercantilist policies of the British Empire and their widespread protection of infant industries was a fundamental driver of its economic transformation (Chang, 2002). ISI, as we saw, was partly a reaction to external influences that was institutionalised and prolonged through public policies (Furtado and Iglésias, 1959; Hirschman, 1968; Pinto, 1973). To list the many ways in which public policy and institutional change can drive structural change processes is futile, for these are countless: infant industry promotion (Chang, 2003), technology forcing regulations (Gerard and Lave, 2007, 2005), tariff barriers (Perez, 1983), trade agreements (Bradford, 1987; Klinger, 2009), and so on. What is relevant, however, is not this listing, but rather to note that – besides technical change, changes in consumption preferences, and fluctuating resource availabilities – deep changes in economic structure may also originate in evolving policies and institutions. A notable case of this is the recent history of Korea, where a 'developmental state' (Chang, 2010; Leftwich, 1995; Woo-Cumings, 1999) that – sometimes dictatorially and sometimes democratically – governed for several decades in the second part of the XX century has been shown to have been crucial in this country's remarkable catch-up process (Amsden, 2001, 1989; Kim, 1997).

The variety of ways in which public policies can drive structural change processes, and the many examples of public policies achieving just this that one can find in history, may make it sound like all it takes to catch-up with the techno-economically advanced countries is for policy makers to get set on the goal of changing the structure of the economy so that the modern, high-returns activities of the latest techno-economic paradigm are embraced. However, this is far from easy. For every successful catch-up process, there are several failed or only partially successful ones: the USSR, most African countries, many South American countries, and so on (Acemoglu and Robinson, 2013). It is largely because of this difficulty that what the best criteria are for the design of effective economic development strategies has been an active research area for generations of scholars (Todaro, 2014).

For many early economic development scholars, one of the fundamental barriers to structural change was the complementarity of modern-sector investments, and one of the key criterion for the design of effective development strategies was the consideration of these in what, they argued, should be comprehensive simultaneous complementary investment plans. This view, which survives to this day (AFRICA, 2006; Easterly, 2006; Murphy et al., 1988), was most famously formulated in Rosenstein-Rodan's 1943 paper on the 'problems of industrialisation of eastern and south-eastern Europe' (Rosenstein-Rodan, 1943). The argument was that many industrial investments that need to be fairly large in order to reap economies of scale (Chandler and Hikino, 1994) would not be profitable unless they are made simultaneously to complementary investments: an investment in a steel manufacturing plant won't be profitable unless simultaneous investments are made in, say, a machine manufacturing industry that will buy the steel, and a mining industry that will provide the raw materials. Having no guarantee that the complementary investments will also be made, no one from the private sector will be willing to make these large industrial investments, even though they could potentially be profitable. Industrialisation will thus never take place unless the state, the only organisation with the financial and organisational strength to overcome this barrier, embarks on a *big push* of industrialisation, making sure all of the investments are made simultaneously by the private sector or the state itself.

The theory of the big push – or, as is also known, of *balanced growth* – is in stark contrast with an alternative view of the economic development process, one which became known as the theory of *unbalanced growth*. One of the earliest and most enduring formulations of this view was the one put forward by Hirschman in *The Strategy of Economic Development* (1958). Hirschman criticised the view that traditional economies were locked in a state of pre-modern homeostatic equilibrium which only an investment shock could unlock. Instead, he argued, most traditional economies were constantly changing and partially modernising, and as they did so, they were constantly generating further modern sector investment opportunities, which were often in no shortage[3]. Thus, while in balanced growth theory, the modern sector was seen as one large unit – one that contrasted with the traditional sector, as in Lewis's model (1954) – which either emerged in one go or not at all, in unbalanced growth theory the modern sector was heterogeneous and could emerge gradually, sub-sector by sub-sector, activity by activity. Thus, what was needed for traditional economies to develop into modern economies was not a big push of modern sector investments, but rather to spur and direct the transformation process that most of them were already experiencing.

Hirschman went further than this and, besides distinguishing among these two very different conceptions of the structural change process, argued that what prevented some economies from undergoing more rapid modernization was not necessarily that they presented few modern sector investment opportunities. The modernization of traditional (or 'developing', or – in our parlance – 'low-complexity') economies with abundant modern investment opportunities could also be hindered by a lack of ability to seize these opportunities[4] – or, in other words, by lack of entrepreneurship. The idea that lack of entrepreneurship, or misdirected entrepreneurship, could become the main development bottleneck was further explored by many of Hirschman's contemporaries (Baumol, 1996; Leff, 1979, 1978), and is still central to XXIst century economic development thinking (Hausmann et al., 2008; Hausmann and Rodrik, 2003; Rodrik, 2010).

2.2. Capabilities and Development

One more enduring contribution from Hirschman's 1958 book is his formulation of the idea that economic sectors are related to each other through various forms of linkages which vary in strength (Hirschman, 1958, chap. 6). Though he later extended the notion (Hirschman, 1981), his initial idea was that the growth of any sector ought to drive the growth of upstream suppliers (backward linkages) and downstream buyers (forward linkages). As the extent of these linkages was not the same for all sectors, it made sense – all other things being equal – to identify and support the most widely and strongly linked

[3] '… the existence of the new office buildings strengthens demand for a great variety of goods and services: from modern office furniture and equipment …, to parking and restaurant facilities, stylish secretaries, and eventually perhaps to more office buildings as the demonstration effect goes to work on the tenants of the older buildings' (Hirschman, 1958, p. 68).

[4] 'Nevertheless, our diagnosis has one special characteristic: it is not concerned with the lack of one or even of several needed factors or elements (capital, education, etc.) that must be combined with other elements to produce economic development, but with the deficiency of the combining process itself. Our diagnosis is simply that countries fail to take advantage of their development potential because, for reasons largely related to their image of change, they find it difficult to take the decisions needed for development in the required number and at the required speed. … Our diagnosis of backwardness therefore reduces all 'scarce' factors to one basic scarcity.' (Hirschman, 1958, p. 25)

sectors, as doing this would maximise the generation of further modern sector investment opportunities.

Other development scholars, however, have shown that the linkages among different sectors go well beyond Hirschman's backward and forward linkages, and even beyond the fiscal and consumption linkages that he later added to his extended scheme (Hirschman, 1981). Sectors, many argue, are also linked by the degree to which they require similar *capabilities* – which we may for now define as the ability to move from intention to outcome (Dosi et al., 2001). Thus, as with Hirschman's linkages, the rapid growth of a sector can potentially drive the growth of sectors requiring similar capabilities.

Recent scholarship suggests that some important aspects of the pattern of development of many economies can be explained in terms of this other form of linkages. In (Hausmann and Klinger, 2007a) and (Hidalgo et al., 2007), the authors show that the products which countries export more than the average country does – i.e. those in which they have Revealed Comparative Advantage (RCA) (Balassa, 1965) – tend to cluster in recognisable groups. Thus, say, they find that countries that have RCA in the export of bananas are more likely to have RCA in the export of coffee compared to countries that don't have RCA in the export of bananas[5] – even though there are no strong forward or backward linkages among the sectors that produce these two commodities, because bananas are not an input of coffee, and coffee is not an input of bananas. Similarly, countries that export refined copper, knit sweaters, and industrial printers more than the average country does are more likely to export, respectively, raw zinc[6], leather footwear[7], and audio and video recording accessories[8] – even though the forward and backward linkages among these pairs of products are at best weak. The authors argue that the reason their data shows certain pairs of products being systematically exported in tandem – forming, when all pairwise connections are visualized together, a structured network they call the 'product space' – is that these pairs of products require similar capabilities, which they think of as 'Lego' pieces: 'In this analogy, a product is equivalent to a Lego model, and a country is equivalent to a bucket of Legos. Countries will be able to make products for which they have all of the necessary capabilities, just like a child is able to produce a Lego model if the child's bucket contains all of the necessary Lego pieces.' (Hidalgo and Hausmann, 2009).

[5] atlas.media.mit.edu/en/profile/hs92/0803/
[6] atlas.media.mit.edu/en/profile/hs92/7403/
[7] atlas.media.mit.edu/en/profile/hs92/6110/
[8] atlas.media.mit.edu/en/profile/hs92/9013/

Capabilities, however, are certainly not Lego pieces. What, then, are they, and why are they important for structural change and economic development? The literature on the issue is extensive and may be reviewed in many ways, but what is most convenient for our purposes is to build and answer from the ground up, i.e. starting from capabilities at the level of the organisation.

In the 1960s, Michael Polanyi observed that much knowledge is tacit (Polanyi, 1967), i.e. present and available for use in a person's cognitive apparatus without the person being fully conscious of its form and content or even of its presence. As later scholars argued, tacit knowledge is distinct from other kinds of knowledge not just because it is *not codified* but also because it is practically *un-codifiable* (Cowan et al., 2000) – a feature which is important because it means it cannot be acquired passively from books or other such media, but rather must be acquired actively through learning-by-doing and other such means (Arrow, 1962; Thompson, 2010). On a related work, Nelson and Winter (1982) argued that what an organisation can achieve in the short term is largely determined by the *routines* it develops over time. The maintenance of these routines – which, in a sense, are like *the ADN of the organisation* – partly depends on physical support systems (such as computer networks) and codified (or codifiable) knowledge. However, crucially, it also depends on the tacit knowledge of the organisation's staff. Often, this makes these routines very hard to transfer, which is one important reason why many organisations tend to be unique and difficult to imitate. For example, to provide passenger flight services, an airliner depends on its staff enacting a number of routines such as scheduling flights, undertaking scheduled maintenance of aeroplanes, assigning seats to passengers, and so on. These routines partly depend on staff's general computer skills, aeroplane maintenance skills, and other such forms of largely codifiable knowledge. The routines, however, also depend on knowledge about how the airliner's flight scheduling IT system is run, about the specificities of its aeroplane maintenance program, about its idiosyncratic passenger seat assignment rules, and other such forms of largely tacit knowledge. Being largely idiosyncratic, these routines – which determine the airliner's short-term behaviour – make the airliner unique.

The routines of an organisation, in turn, are the building blocks of what Dosi et al. (2001) call its *organisational capabilities*, i.e. of what the organisation can achieve in the short term. If the organisation is to expand the realm of activity it is capable of engaging on, it will have to *invest* in the development of new capabilities, establishing new routines that enable it to do new things. As Dosi et al. put it, in 'organisations, there is a distinction between the execution of high-frequency, repetitive daily business by low level employees and the decisions of executives about the development and deployment of capabilities ([e.g.]

serving … french fries versus opening another hamburger stand). There is a corresponding distinction at the individual level between the relatively tacit, subconscious, automatic, and high frequency character of exercise and the more intentional, deliberate, and intermittent processes involved in skill development and deployment (learning to drive or choosing the destination versus the exercise of skill in keeping the car on the road). The parallels extend to learning processes; different processes are involved in the sort of learning that improves exercise than in original development of skills and capabilities.' (2001, p. 4).

The realisation that organisations have limited capabilities, and that developing new capabilities takes time and resources, has had significant implications for economic development thinking. As is well known, structural change in lower-complexity economies largely hinges on the acquisition of technology that has been developed in the more advanced countries (Perez, 2010; Perez and Soete, 1988; Verspagen, 1991). For a long time, it was thought in development circles that acquiring technologies was equivalent to building modern industrial plants and furnishing them with modern industrial machinery. However, years of experience showed that this was not the case: in catching up economies, the same plants with the same machinery often worked at much lower levels of productivity than they did in the central economies (Bell and Pavitt, 1995), and sometimes did not work at all (Sutton, 2005). Research on the matter made it clear that, often, the reason was that the organisations attempting to acquire the modern technology did not have the capabilities needed to use it and adapt it. Technology, they came to understand, is not fully embodied in artefacts such as machinery, which is why its adoption was often a failure for organisations that did not invest in developing the required capabilities.

Although not all organisational capabilities relate to technology (Teece et al., 1997), those that do – which most scholars refer to as *technological capabilities* – are widely seen as crucial to economic development (Bell, 2009). By studying the history of firms that were able to master modern technologies, researchers have found that the accumulation of technological capabilities is a lengthy process that sometimes takes decades; the process, moreover, usually follows a recognizable sequence, starting from the capability to *use* technology, passing through the capability to *modify* it, and finishing with the capability to *design* new forms of it (Bell, 2006; Figueiredo, 2003; Katz, 1997, 1984; Mayer, 1996). Noting that the mere *use* of technologies often requires innovative efforts to adapt it to the local conditions, researchers have challenged the assumption that 'a sharp distinction can be drawn between technological innovation and the subsequent diffusion of technology' (Bell and Pavitt, 1995). Time has also made it clear that much of the process of acquiring technological capabilities takes place at the firm level: being partly composed of tacit knowledge idiosyncratic to the firm, technological capabilities cannot be fully codified in, say, courses to be taught in universities or other training centres. Some learning can only take place by doing (Arrow, 1962; Dutrénit et al., 2013), but this doesn't mean that learning can be expected to take place automatically: the evidence, in fact, points in just the opposite direction: acquiring technological capabilities requires sizable and focused capability acquisition investments that are often all but automatic by-products of normal activity (Battisti and Pietrobelli, 2000; Dutrénit, 2000; Kim, 1997).

Research on the significance of firm-level capability accumulation efforts in country-wide catch-up processes – which is especially abundant for the Asian economies – shows that, as countries such as Korea and Taiwan caught up with the advanced economies, their firms went through extensive capability accumulation processes, usually following the sequence described above. More interestingly, scholars have found that the State was often deeply involved in these processes. Kim (1997) has shown how the Korean state used all sorts of policies – subsidies attached to capability accumulation requirements, the deliberate imposition of crises on firms, picking winners, and many others – to spur the development of new capabilities on Korean chaebols. Furthermore, Amsden has shown how much the same was true for many other countries, not just in Asia: in her words, the 'developmental state was predicated on performing four functions: development banking; local-content management; "selective seclusion" ...; and national firm formation. As a consequence of these functions ... "'the rest" finally made the requisite three-pronged investment to enter basic industry ...' (Amsden, 2001, p. 125). The majority of countries that caught up with the more advanced economies in second part of the XX century were not, in fact, those that followed the Washington Consensus of 'liberalization, privatization, and price-flexibility' (Cimoli et al., 2009), but rather those where the state directly undertook to speed up the capability accumulation processes of firms, leading them to make the same 'three-pronged investments' in a) up-to-date machinery and plants of optimal scale, b) managerial hierarchies and technological skills, and c) distribution networks, that allowed the US, Germany and Japan to leap to the forefront of the world economy in past centuries (Amsden, 2001; Chandler and Hikino, 1994).

The finding that capabilities – all kinds, not just the technological ones – largely reside at the firm – the microeconomic – level does not, however, mean that their development is unaffected by what happens at the macroeconomic level. On the contrary, scholars have repeatedly shown that macroeconomic factors loom large in firms' ability and incentives to develop new capabilities (Cimoli and Porcile, 2013; Katz, 2001). However, since firms have different capabilities, they are heterogeneous, and therefore macroeconomic factors do not affect all of them in the same ways. Thus, country-level capability development processes cannot be solely explained in terms of macroeconomic forces: firms differ, and their differences matter (Nelson, 1991). What happens with them is not just the explanandum: it must also be part of the explanation.

That every firm has its own idiosyncratic capabilities should also not be extended to mean that what a firm has acquired the capability to do is irrelevant to other firms. The accumulation of capabilities in general, and in particular of technological capabilities, generates positive externalities or *spillovers* that affect other firms (Griliches, 1991; Iammarino and McCann, 2006). Lall (1980) notes that, often, business to business transactions are *not* arms-length but rather close contractual relations of mutual cooperation; he then goes to show how an implication of this fact is that the process of accumulation of capabilities of either part of the transaction affects that of the other. As the highly capable truck manufacturing company in India that decides to outsource the manufacturing of pistons and fuel injectors provides all sorts of technical and non-technical assistance to the suppliers it has chosen to procure these from (Ibid.), the capability accumulation process of countless firms depends on what its partners do. Linkages such as these are moreover one of at least five channels through which these kinds of knowledge spillovers (Nieto and Quevedo, 2005) may take place, the other four being demonstration/imitation, labour mobility, exports, and competition (Crespo and Fontoura, 2007).

Lall and many others, however, also point that these and other forms of spillovers are not to be taken for granted: the truck manufacturer may well not build virtuous local linkages, and instead outsource things to a foreign firm. Because many countries bet on the attraction of foreign direct investment (FDI) as a development strategy (Lall and Narula, 2006), and because FDI is often accused of being a double-edged sword – one that may generate positive spillovers but also crowd out domestic firms and investment (Agosin and Machado, 2005; Amsden, 2009) – the issue of the magnitude of these spillovers and the question of whether they outweigh the alleged downsides is a contentious one. On this matter, decades of research have shown that sometimes FDI spillovers are sizable and sometimes they are not. This has led researchers to accept that the answer to the question is not simple, and to look for policies and circumstances that may ease their realisation (Crespo and Fontoura, 2007). Their clearest finding is that FDI spillovers are much more probable where there is a good deal of country-level absorptive capacity on the FDI destination (Cohen and Levinthal, 1990; Fu, 2008; Nieto and Quevedo, 2005). However, they have also found that spillovers effects do not just depend on policies and circumstances:

they also depend on firm specificities. For example, in their studies on Argentina, Marin and Bell (2010, 2006) show that the magnitude of Multi-National Corporation's (MNCs) spillovers varies significantly for firms that, by being in the same country and the same industry, face similar policies and circumstances.

Further contributions to understanding what facilitates the creation of knowledge spillovers from FDI – and, through that, the development of domestic capabilities – has come from the body of research that goes under the name of Global Value Chains (GVCs). In (Gereffi and Korzeniewicz, 1994), the authors note how the production of many goods is organised on a global scale: in building the Boeing 787, the wingtips are made in South Korea, the fuselage in Italy, the wings in Japan, and the tail fin in the US [9]. As with the relation between the aforementioned Indian truck making firm and its suppliers, the transactions in these global value chains are often *not* arms-length, but are rather organised in complex governance structures. In (Gereffi et al., 2005), the authors distinguish among five different modes of governance according to a) the complexity of the transactions, b) the codifiability of the knowledge-base that supports them, and c) the capabilities required from of those at the bottom of the GVC. These five modes are market governance, modular governance, relational governance, captive governance and hierarchical governance. Notably, the ability of firms entering at the bottom of these global chains – and it is at their bottom that the firms of lower-complexity countries often have to enter – to develop new capabilities and *upgrade* to higher returns activities is strongly affected –and can sometimes be largely impaired – by the prevailing mode of governance. Likewise, the strength of spillovers from FDI can often be determined by its position on these GVCs (Cattaneo et al., 2013; Giuliani et al., 2005).

The capabilities of firms, as we have seen above, are arguably the most important components of the capabilities of countries as wholes. These, therefore, are certainly part of the 'Lego' pieces Hidalgo and Hausmann compare them to (Hidalgo and Hausmann, 2008): to a large extent, it is because firms that have the capabilities to produce refined copper, knit sweaters, and industrial printers are not far from being capable to produce, respectively, raw zinc, leather footwear, and audio and video recording accessories that these three pairs of products are close to each other in the product space (Hausmann and Klinger, 2007a). However, research on Innovation Systems (ISs) has shown that the capabilities of countries as wholes are more than the mere sum of the capabilities of their firms (Freeman, 1995; B.-\AAke Lundvall, 1992; Nelson, 1993) – and, more generally, that the capabilities of all economic systems – such as sectors (Malerba, 2004) or international

[9] www.afdb.org/fr/blogs/integrating-africa/post/climbing-value-chains-options-for-african-policy-makers-12385/

production networks / GVCs (Bergek et al., 2008; Carlsson, 2006) – are more than the sum of the capabilities of their constituents. The view that, when it comes to capabilities, the sum is more than the parts, originates in the observation that much of what enables people and organizations to do what they do stems from their relation with other people and other organizations, and is therefore not attributable to the people or the organization themselves but rather to their inter-relationships (Lall, 1980; Rodriguez-Clare, 1996); and also from the observation that much of what makes them capable of doing certain things stems from their ability to benefit from various forms of physical, knowledge, and organizational capital (Bell, 2009) that are not always attributable to any single economic agent, such as 'property rights, regulation, infrastructure, specific labor skills, etc.' (Hidalgo and Hausmann, 2009). Thus, the capabilities of economic systems as wholes are an emergent property (Bunge, 2003) which is closely related, but is not reducible, to the capabilities of its individual organisations.

2.3. Sectoral Transformation

As we reviewed the literature on structural change, we saw that some of the main forces leading to large-scale changes in economic structure were technical change, changes in consumption preferences, fluctuating resource availabilities, and evolving policies and institutions. And, as we reviewed the literature on capabilities and development, we saw how such changes were largely underpinned by processes of accumulation of capabilities that take place largely (but not only) at the firm level. This sets the stage for a review of an associated body of literature, one that is most directly relevant to this thesis because, instead of looking at structural change in the aggregate (as in Section 2.1) or through its key micro-foundations (as in Section 2.2), it looks at what we may call its key *meso-foundations*. These are the sectoral emergence and transformation processes which regularly take place in modern economies, and which are our primary concern.

Like much of what we have already gone through, this literature heavily builds on the works of Marshall, Schumpeter, Kuznets, Clark, Chenery and Rostow, whose writings 'envisaged a broad dynamic qualitative analysis of the emergence, development and decline of industries', setting 'the stage for subsequent studies of the factors that affect the structural evolution of industries' (Malerba and Orsenigo, 1996)[10]. This view of sectors as evolving entities is related, but different, from three lines of scholarship that have also studied sectors in detail but that have treated them as static, thus explaining their

[10] This section is heavily indebted to, and organized along the same lines of, this excellent review of this literature.

organization but not the way they change: the studies on the 50s and 60s about structural organization by Mason, Bain and others (for a review see Cohen et al., 1989), which focused on explaining market structure and were the basis for the structure-conduct-performance model purporting to explain the hazards of industrial concentration; the transaction costs economics of Williamson and others (Williamson, 1981, 1979), focused (among other issues) on explaining the make/buy decision in the context of institutional rules governing exchange; and the 'New Industrial Organization' literature, largely based on game-theoretic perspectives on strategic choice and often focused on explaining the strategic behavior of firms (Jacquemin and others, 1987).

Understanding how sectors change is easier if one can first gain knowledge about the ways in which they tend to be similar and the ways in which they can differ. There are several respects in which most sectors tend to be similar. First of all, one commonality of most sectors is that they are seldom composed of similar firms: studies have found that firms in most sectors tend to differ in productivity (Baily et al., 1985), profitability (Geroski and Jacquemin, 1988), innovativeness (Patel and Pavitt, 1991), and several other respects (Nightingale and Coad, 2013). Most significantly, they tend to differ in size, but in this area, the differences typically form a stable macro pattern such that the size distribution of firms is skewed and resembles a Pareto distribution (Ijiri and Simon, 1964; Simon and Bonini, 1958). Sectors are also similar in that most show high rates of entry and exit of new firms, but the entries and exits tend to happen at the fringe: the firms at the core of the industry – the leaders – seem to be much more stable (Acs and Audretsch, 1990; Beesley and Hamilton, 1984; Breschi et al., 2000).

Despite their variety, firms within the same sector do tend to share some significant similarities. In particular, they tend to share similarities in the way they relate to scientific and technological knowledge. These similarities were notably summarised by Keith Pavitt in his 1984 study of patterns of technical innovation in British firms since 1945 (Pavitt, 1984). Pavitt showed that, depending on the sector, either of four distinct kinds of firm, each with their own different way of innovating, was predominant: *supplier dominated*, *scale intensive, specialised supplier*, or *science based*.

Supplier dominated firms are generally small and tend to have weak technological capabilities. Typically, their competitive edge comes from being faster to adopt new technologies supplied by other sectors (and, in this and other ways, cut costs), and not from in-house technological innovations in products or processes. These firms have tended to dominate the traditional manufacturing sectors (textiles, lumber, paper and wood); and also the agricultural, construction, and commercial sectors.

Scale intensive firms tend to be large and have strong process engineering capabilities. Their competitive edge comes from running large production facilities able to seize economies of scale, and from their constant improvement of the productivity of such facilities through their process engineering innovations. These firms have typically dominated in continuous manufacturing sectors such as steel and glass, and also on some durable consumer goods sectors.

Specialised supplier firms tend to be small or medium-sized suppliers of technology – often, technology for scale intensive firms – with strong product engineering capabilities. Their competitive edge comes from their ability to cater to the needs of certain niches, be more innovative than their rivals in those niches, and appropriate the returns of their niche innovations. These firms have often been predominant in sectors such as machine tools and software.

Science based firms, finally, are sometimes small and sometimes very large, and tend to have very strong technological capabilities rooted in a knowledge-base built more on scientific than on technical knowledge. Their competitive edge comes from their ability to come up with the more radical and disruptive kinds of innovation, and to profit from the temporary monopolistic position which they are likely to gain when these innovations succeed. These firms have been common in the electronics and the biotechnology sectors, among others.

By showing how patterns of technical change vary among sectors, Pavitt's taxonomy was an important addition to our understanding of sectoral differences. Building on this contribution, further research has uncovered yet some more ways in which sectors' patterns of innovation vary systematically. In this regard, Malerba others have made a distinction between what they call Schumpeter Mark I and Schumpeter Mark II sectors[11]. The former, as they define them, are characterised by low degrees of concentration, large numbers of innovators, high rates of entry, and high degrees of instability in the hierarchy of innovators. The latter, conversely, are characterised by high degrees of concentration, low rates of entry, and a stable hierarchy of innovators. In a study of 437 European business covering 69 four-digit ISIC manufacturing sectors, these authors propose an explanation of why sectors may come to resemble more one or the other of these two ideal types, and show empirical data to support this explanation (Breschi et al., 2000)[12]. Sectors, they argue, tend

[11] The distinction is inspired by the two contrasting views that Joseph Schumpeter had of entrepreneurship at the early and late stages of his career.

[12] In their study, the authors show that sectors in the following technological classes fit the Mark I pattern: civil engineering; mechanical; electrical technologies; mining, railways and ships; natural,

to resemble one or the other pattern because of differences in what they call their *technological regime* – a notion which they had proposed in an earlier work (Malerba and Orsenigo, 1993), and which they trace back to (Nelson and Winter, 1982).

According to these authors, a sector's technological regime is defined in terms of its *technological opportunities* ('ease of innovating for any given amount of money invested on search'), its *cumulativeness conditions* (the extent to which today's 'innovations and innovative activities form the base and the building blocks of tomorrow (sic) innovations'), its *appropriability conditions* (the ease of 'protecting innovations from imitation and of extracting profits from innovative activities'), and *the nature of its knowledge base* (its complexity and the degree to which it depends on tacit knowledge) (Malerba and Orsenigo, 1993, pp. 3–6). In their interpretation of the findings of their study, high technological opportunities, low appropriability conditions, low cumulativeness conditions, and a knowledge base grounded in scientific expertise lead to sectors with a Mark I pattern of innovation. And, conversely, low technological opportunities, high appropriability conditions, high cumulativeness conditions, and a knowledge base grounded on technological expertise lead to Mark II sectors (Breschi et al., 2000).

By placing sectors in certain categories, Pavitt's and Breschi-Malerba's taxonomies may make it look like the features of the organisation of sectors on which they focus are static. However, this is not so. As seems to have happened with parts of the financial services sector – which Pavitt had placed in the supplier dominated category, but which, in the area of trading floor activity, has increasingly come to rely on mathematics and computer sciences and has therefore gotten closer to the science-based category – sectors may move from one category to another of either scheme. But although many recognise that sectors evolve through time, there is only one well-developed theory about how they do so: the Industry Life Cycle (ILC) theory.

ILC theory was developed by Klepper and others (Horvath et al., 2001; Klepper, 1997). The theory draws heavily from the work of Utterback and Abernathy (1975) on the product life cycle. These last authors noted that product innovation often follows a pattern where widely differing product designs compete until one comes to dominate. This is, for example, what happened with the early car industry: car designs competed until the Ford

artificial fibers; paper; household electrical appliances; industrial machinery; medical preparations; measurement and control instruments. And the sectors in the following classes fit the Mark II pattern: organic chemicals; miscellaneous chemical compounds; macromolecular compounds; electronic components; gas, hydrocarbons, oil; agricultural chemicals; consumer electronics; engines, turbines and pumps; vehicles.

Model T came to dominate. Building on this insight – and on much empirical research – Klepper proposed that, as they develop, sectors go through three stages. In the first stage, the firms of a sector focus on product innovation, and compete to establish their product designs as the dominant ones. In this stage, sectors' pattern of innovation tend to fit the Mark I pattern, with lots of innovators, high rates of entry, and an unstable hierarchy at the top. The second stage starts when the dominant design has been established. In this stage, firms focus on process innovation and compete by reducing production costs, this in order to gain higher market shares by selling cheaper. The second stage is often marked by a 'shake-out' of firms, one that eliminates those that fail to adopt the dominant design. This shake-out helps to shift the pattern of innovation in the sector to the Mark II pattern: fewer innovators, lower rates of entry, and a more stable hierarchy at the top. In the third stage, innovation decays as the dominant design becomes well established and opportunities to lower production costs by process innovations are exhausted. At this stage, the industry has typically shifted to a highly concentrated Mark II pattern, with a few oligopolistic dominant firms at the top of a stable hierarchy of leaders. The cycle may then be reset and start all over again when disruptive/radical innovations – often, as Christensen has shown (1997), by firms outside the oligopolistic structure – turn the dominant designs obsolete – as happened with the replacement of VCR players by DVD players.

While the ILC theory works well to explain the evolution of several sectors (e.g. tires and television sets) other than those from whose study it was inducted (automobiles), it is limited in several important respects. First of all, the theory does not explain the evolution of primary (mining, agriculture, forestry, etc.) and tertiary (service) sectors as well as it explains the evolution of secondary (manufacturing) sectors, this largely because it was not designed to do so (Nelson and Winter, 2002). Second, the theory equates a sector with a product, which limits its applicability: in sectors such as chemicals, firms typically produce numerous families of related products, and process innovations are at least as important as product innovations; and many products, such as airplanes and flight simulators, are in fact complex product systems (Hobday, 2000, 1998), systems that depend on the integration of the output of a wide range of interdependent inputs, each of which may go through its own semi-independent product life cycle. Third, the theory fails to account for the fact that, often, radical innovations do not bring about the emergence of wholly new sectors, but rather the structural transformation of previously existent ones: as happened with the computer sector, the radical innovation of the personal computer – one of many in this sector's history – saw the rise of many new actors and product lines and the emergence of whole new classes of demand, but it also saw the reconfiguration of an already existent sector that had previously been focused on mainframes for large niche users such as the military (Malerba et al., 1999).

Some of these and other limitations of research on 'the dynamics and evolution of industries' (Malerba and Orsenigo, 1996), such as the role of institutions and linkages to users and suppliers, have been tackled by research on Sectoral Systems of Innovation (SSI). This literature, pioneered by Malerba (Malerba, 2002), is derived from NSI studies. What it proposes is not really a theory about sectoral transformation, but rather a framework for studies of sectoral organisation and transformation that is not blind to important sectoral phenomena which other studies tend to neglect.

Studies cast in this framework (Malerba, 2004 contains six such studies about sectors in European countries) adopt a broad and open definition of sectors and try to understand their organisation and evolution by looking at them from four points of view. The first is a sector's knowledge base and its learning processes. These are closely related to its technological regime (which, as we have seen, influences its structure and the nature of its leading actors, and may vary over time). The second is a sector's actors and the networks these weave. In SSI studies, these actors include not just the firms that produce the final outputs, but also the intermediaries that many of the original NSI studies found to be key for national innovative performance: suppliers, universities, research institutes, government bodies, technology transfer agencies, professional associations, trade unions, etc. (Freeman, 1995; B.-\AAke Lundvall, 1992; Nelson, 1993). Regarding the networks that these actors weave, the point in SSI studies is to recognise that these are complex and full of links which are not just simple market transactions. The third point of view from which SSI studies look at sectors is the institutional one: institutions – the norms, routines, habits, practices, rules and standards that shape the cognition of actors and the way they interact – are key to understanding the trajectory of development of a sector and its performance. And the fourth and final is the nature of a sector's demand: SSI studies recognize that key features of demand – such as the sensitivity of customers to advertising, the strength of bandwagon or network effects, the heterogeneity of customer needs, or the availability of niche markets and experimental users (Malerba et al., 2007) – vary from one sector to another, and that these variations shape the way they develop.

While the SSI framework originated and was first applied to understand the evolution of sectors in the advanced economies, it has also been applied to study sectoral catch-up processes in lower-complexity economies. A number of studies in this line were published in *Economic Development as a Learning Process: Variation Across Sectoral Systems* (Malerba and Nelson, 2012). The studies included successful, ongoing, and failed catch-up processes in the pharmaceuticals, automobiles, software and associated services, telecommunications equipment, agro-food, and semiconductors sectors in several different countries. The comparison of these studies – which, covering catch-up processes in various sectors, in various countries, and of various outcomes, constitute a very rich sample – show that successful sectoral catch-up processes share at least four similarities. First, in all successful catch-up processes, the main success factor was the ability of firms to progressively develop more advanced capabilities. Second, in all successful cases 'active efforts to learn about and master know-how possessed by firms in frontier countries was a major input for the learning processes of domestic firms'; however, the channels by which this transfer of knowledge took place were variable. Third, in all successful cases, the catch-up process was fostered by a strong development of skilled human capital, which was often fueled by the arrival of internationally mobile labour and by high-level training of nationals in foreign universities. And, fourth, in all successful cases 'active government policy … stimulated learning and capability formation by domestic firms' (Malerba and Nelson, 2011).

The studies, however, also showed important differences among sectors and countries. One area of significant differences was the nature of the leading firms. The kind of firm that led the catch-up process was not the same in all cases: where economies of scale and large R&D expenditures were important – such as in telecommunications – these were always large firms; but where 'the knowledge base [was] more varied, technological entry barriers [were] low, economies of scale and scope [were] not high and a division of labor [was] possible' – such as in software and agro-food – these were often small and medium-sized firms. Also, the role of multinationals, good or bad, was not always the same: in some cases, these were at the head of global value chains, and their influence had to do with this role and its effect on possibilities to upgrade; and in other cases, these opened subsidiaries in the catching-up countries and influenced the process through this more direct channel (Malerba and Nelson, 2011).

A second area in which sectoral catch-up processes differed was the role of demand and vertical links. Demand and vertical links always played an important role, but this role was different depending on whether this was 'demand for standard products' or 'demand for custom or segmented products'. Demand for standard exportable products was a key driver for catch up in sectors such as semiconductors and pharmaceuticals, while – when it was large enough – domestic demand for custom or segmented products, such as customised software, created niches that domestic firms could use and that would protect them as they developed their capabilities. Also important were the 'vertical links between users and producers, and between producers and suppliers'. In cases, these fueled the catch-up process: in China, local auto production led to the development of local auto *parts* production. However, this was not always the case: in Korea, local auto producers were not willing to rely on domestic auto part producers because they did not trust these could reach their quality standards, and thus choose to source most auto parts from abroad. For the authors, a key reason for this difference was that, while auto production in Korea was focused on the highly-demanding export market, in China it was focused on the far less demanding domestic market (Malerba and Nelson, 2011).

The comparison of the studies in this collection led to interesting reflections on several other aspects of sectoral catch-up processes: on the different the roles played by universities and public research laboratories; on the different forms of finance that dominated depending on whether the main innovative actors were start-ups or large firms; on the different policy instruments used to drive firms to develop new capabilities; on the enabling, and sometimes blocking, role played by institutions; and on several other respects. However, perhaps the most important conclusion to derive from them is that, as the authors put it, 'economic development proceeds to a considerable extent at the sectoral level, and sectors vary significantly regarding the conditions required to spur successful catch up' (Malerba and Nelson, 2011, p. 1668). In consequence, some countries succeeded in catching up in some sectors, but failed to do so in others. Thus, it is not just firms that differ: sectors do so too. And their differences also seem to matter.

2.4. Research Gaps

Our goal, recall, is to understand how new *infrastructure* sectors develop. Based on what we have learned, this question may also be framed as a question of sectoral transformation: the process of development of a previously inexistent high-speed passenger railroad infrastructure sector is, at the same time, the process of transformation of an existent land transportation infrastructure sector. Whether we formulate the question as one of new sectoral development or as one of sectoral transformation, the three bodies of literature that we went through above are highly relevant. Each of them has significant things to say about how new sectors emerge and about how established sectors are transformed.

Infrastructure sectors, however, are somewhat of a blind spot within these bodies of literature. While many studies about structural change, capabilities, and/or sectoral transformation focus on – or at least take into account the existence of – manufacturing and/or services sectors, and some even consider primary sectors (e.g. Adewuyi and

Ademola Oyejide, 2012; Morris et al., 2012), few take a specific look at infrastructure sectors. In the case of studies about structural change, these are often carried at such high levels of aggregation that infrastructure sectors are unidentifiable (e.g. the primary, secondary and tertiary sectors of Echevarria, 1997). Or at such high levels of abstraction that only very basic sectorial differences (such as whether the sector is one that produces intermediary or final consumption goods) are acknowledged (e.g. Aghion and Howitt, 1990). And when structural change studies are not highly abstract and focus on lower aggregates, these aggregates are rarely infrastructure sectors: most often, they are manufacturing sectors (e.g. Salter, 1960). In the case of studies about capabilities, these typically assume the existence of an appropriate physical infrastructure as a sort of 'foundational' capability which needs to be in place for primary, secondary, or tertiary sectors to develop, and rarely dealing with the issue of how the infrastructure got there in the first place (e.g. Hidalgo and Hausmann, 2009). And much the same happens with the literature on sectoral organisation and evolution, where infrastructure sectors rarely make it to comparative studies (such as Malerba, 2004; Malerba and Nelson, 2011) or are considered in theory-building efforts (such as Klepper, 1997).

On top of the above, the three bodies of literature we reviewed above, and the issues they point to, have only rarely been integrated into empirical studies that consider the broad forces that research acknowledges as the main structural change drivers, but also the sectoral and firm-level specificities of structural change processes. For example, structural change studies that pose productivity improvements stemming from technological innovations as a key structural change driver normally stop short of inquiring about the broader sectoral and firm-level changes that accompany these improvements (Krüger, 2008). And knowledge about sectoral change such as that embodied in the ILC theory (Klepper, 1997) makes little reference to the structural forces that favour the emergence of certain kinds of sectors over some others. Only in rare cases, such as in (Malerba and Nelson, 2011) or (Amsden, 2001), one can clearly see an effort to integrate these related issues – but then again not for infrastructure sectors.

In the rest of this study, our academic goal will be to contribute to knowledge about structural change processes by addressing the two shortcomings detailed in the previous paragraph, which we may summarize as *lack of consideration of the specificities of infrastructure sectors* and *lack of integration of the literatures on structural change, capabilities and sectoral transformation*. At this point in the study, the question that guides us (*how do new infrastructure sectors develop*?) is still very broad. However, we will be able to make it much more specific, and detail how we will tackle it, by the end of the next chapter, after we have laid out the theoretical framework that will guide the rest of this work.

Chapter 3

Theoretical Framework and Research Design

In this chapter, we will develop the theoretical framework that will underpin this study, and then detail its research questions and its research design. The first section, which deals with the first of these tasks, is divided into four parts. The first of these aims to better define sectors, our primary units of analysis. The other three develop the main analytical concepts that we'll use to organise the inquiry: entrepreneurial opportunities, the entrepreneurial function, and capabilities. The second section, on research design, is divided into five parts. The first characterizes the institutional context of the economy we will look at on the empirical chapters. The second states our formal research questions. The third introduces the three case studies that we will use to answer these questions. The four explains the study's analytical strategy. And the fifth and final details the main data sources and methodologies that we will use.

3.1. Theoretical Framework

The goal of this section is to develop a framework that enables us to better identify the phenomenon to be analysed, the factors that may influence this phenomenon, and the mechanisms connecting these factors to the phenomenon. For this, we will need to do two things. First, come up with a description of sectoral emergence processes which is general enough to apply to a broad range of sectors in a wide variety of circumstances, noting, as we go along, how different instances of these processes may vary from each other. And, second, identify the factors that may lead to these variations, noting in each case how they may do so. In confronting these tasks, it will be useful to keep in mind that the factors that may influence the trajectory of development of an emergent sector are not all quantifiable, and may, moreover, interact and affect the process in non-linear ways. Hence, it will not always be possible to establish straightforward relations of the kind that link increases in one variable to increases or decreases in another. Thus, what we aim for in what comes next is a framework geared for a qualitative inquiry – even though, as we will see, this inquiry will be informed by a wealth of quantitative information.

3.1.1. Sectors, Sectoral Development and Innovation

Sectors are subsets of larger economic systems. Since there are many ways of dividing economic systems, there are many ways of defining sectors. Perhaps the best-known example of a sectoral definition is the one that stems from the work of Alan Fisher, Colin Clark and Jean Fourastié (Clark, 1940; Fisher, 1939; Fourastié, 1954), who came up with the widely used division of economy in three sectors: the extraction of raw materials including mining and agriculture (primary sector), manufacturing (secondary sector), and services (tertiary sector). The sectoral emergence processes we are interested in, however, take place at a far more disaggregated level than these broad divides. At the level we'll be concerned with, one of the most systematic and thorough divisions of the economy is the International Standard Industrial Classification of All Economic Activities (ISIC) (United Nations, 2008). ISIC groups 'producing units into detailed industries based on similarities in the economic activity, taking into account the inputs, the process and technology of production, the characteristics of the outputs and the use to which outputs are applied' (United Nations, 2008, p. 26). In this study, we will use the same grouping principle that this scheme does, and define sectors based on their key inputs, their key outputs, and their key production processes. Also, again like ISIC, we will consider sectors to be composed of the economic agents that engage in these key production processes. We will not, however, use ISIC's sectoral categories, for none of these captures the key inputs, outputs, and production processes of the infrastructure sectors that we will be studying.

ISIC is a hierarchical classificatory scheme which is regularly updated to reflect changes in economic systems, and which, in its fourth revision, comprises 21 sections, 88 divisions, 238 groups and 419 classes. In such a scheme, the appearance of a new class signals recognition of the development of a new sector which has grown big enough to have its own 4-digit-code. In ISIC, however, the appearance of a new class (or the disappearance of one, or the merging of two or more) is at the same time a transformation of the 3-digit group, 2-digit division, and 1-digit section to which it belongs. This, as we've seen, is a reflection of the way in which economic systems evolve. The transformation of broadly defined sectors such as 'agriculture' or 'manufacturing' is a process whereby economic agents introduce innovations or clusters of innovations that change the sector's established practices in substantial ways. Sometimes, these innovations have considerable potential and over time lead to the organised mobilisation of not just a few but many economic agents. In these cases, as time goes by, it becomes possible, and for some purposes useful, to distinguish the emergent and more narrowly defined sectors that are based on these innovations from other sectors. But the development of these new sectors is always part of the process of transformation of more broadly defined sectors.

We saw, however, that innovation in the advanced economies typically has a different character than innovation in lower-complexity economies. In the former, first of all, cases of economic agents introducing goods, processes, services, business models, etc. which had never been tried before – or what we may call *new-to-the-world* innovation – are more common than in the latter. Moreover, the rate of the adoption of innovations that first appeared in other countries – or what we may call *new-to-the-country* innovation – is also higher in the advanced economies. Catching up is thus about increasing both the rate of new-to-the-world vs. new-to-the-country innovation, and the rate of adoption of new-to-the-country innovation (Fagerberg et al., 2005). In this study, however, we will only be concerned with the second challenge, meaning that the innovations which we will consider will be of the new-to-the-country kind. These, it would seem, are the more important when it comes to infrastructure sectors, for new-to-the-world infrastructure innovations are seemingly less frequent than new-to-the-world innovations in other sectors. Thus, practically all of the innovations that underpin the sectoral emergence processes we will be looking at will be new-to-the-country, and we will not be concerned with how these innovations emerged in the countries they were first introduced into.

The introduction of innovations is often deemed to be one of the main functions of entrepreneurship. Although what individual entrepreneurs and entrepreneurial organizations – for short, *entrepreneurial agents* – do is not always as bold as Schumpeter's original and heroic view of these key economic agents (Schumpeter, 1912), most scholars regard innovativeness and willingness to take risks as features that distinguish them from more passive kinds of actors (Lumpkin and Dess, 1996). As we saw, one of the fundamental dynamics of new sectoral development processes is the introduction of innovations. Therefore, a fundamental part of comprehending these emergence processes is understanding how entrepreneurship takes place in them, i.e. understanding what we will call below *the entrepreneurial function*. Entrepreneurship, however, never occurs in a vacuum: there is always a context that influences whether a certain kind of innovation has a good or a bad chance of being successful, i.e. whether or not the innovation is what we will later call an attractive *entrepreneurial opportunity*. Grasping this context – and, in particular, those parts of it that most influence the potential performance of the innovation in question – is thus just as important to make sense of sectoral emergence processes as is understanding entrepreneurship. The success of entrepreneurial agents, however, is not *just* a function of the worthiness of the entrepreneurial opportunities shaped by this context: it is also a function of their ability to access the *capabilities* required to pursue these opportunities successfully. Finding out how entrepreneurial agents access these capabilities is also a key part of understanding how new sectors develop.

Thus, at a very general level, the process by which new sectors develop may be framed as one where the entrepreneurial function, which consists in pursuing entrepreneurial opportunities, is performed by entrepreneurial agents able to access the capabilities that this requires (Figure 3.1). In consequence, the problem of understanding new sectoral development processes may be tackled in three steps. The first is to understand the nature of these entrepreneurial opportunities and the nature of the context that shapes them. The second is to understand the nature of the entrepreneurial function and the nature of the entrepreneurial agents that perform it. And the third is to understand the nature of the capabilities that agents these need to access to perform the entrepreneurial function, and the way in which they access them. In what follows, we will see what each of these three steps involves.

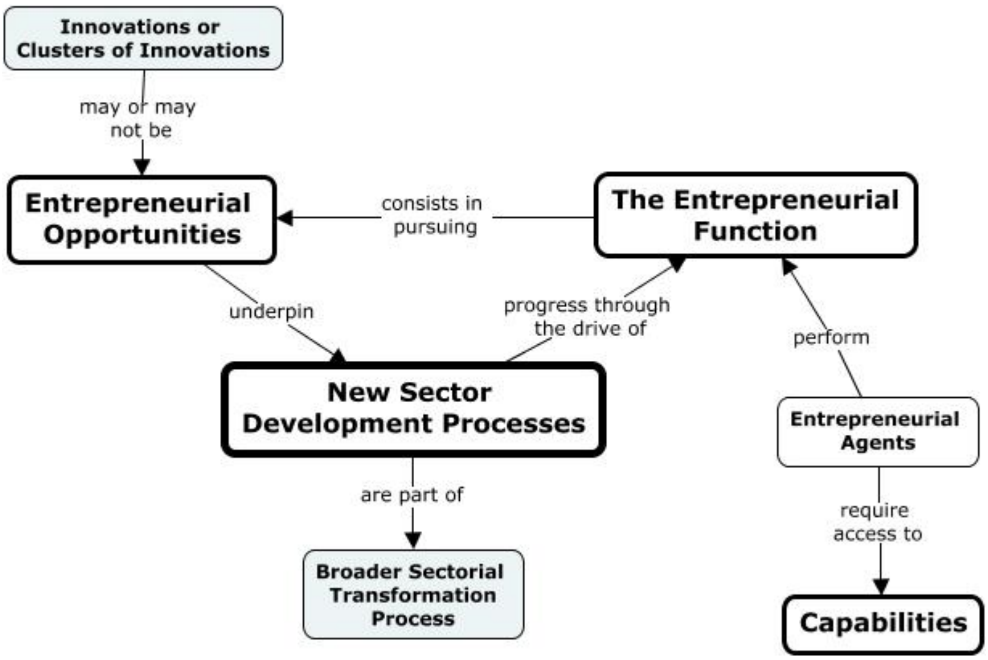

Figure 3.1: Concept map of the main elements of the theoretical framework. *New sectors develop as entrepreneurial agents with access to the required capabilities pursue the entrepreneurial opportunities that underpin them, i.e. as they perform the entrepreneurial function.*

3.1.2. Entrepreneurial Opportunities

Casson (1982) defined entrepreneurial opportunities as ‘those situations in which new goods, services, raw materials, and organising methods can be introduced and sold at greater than their cost of production’. Casson, in other words, defines entrepreneurial opportunities as opportunities to introduce innovations – as defined by Schumpeter (1912)

– at a profit. In this study, we will adopt the same definition, though as we will see below with two refinements. With this definition, a mining sector that sits in a desert and uses large amounts of desalinated water pumped from the nearest coast is an entrepreneurial opportunity for anyone that can develop a new minerals processing method that can work with less or salty water. And a salmon farming industry that is plagued by disease is an entrepreneurial opportunity for anyone that can develop a more environmentally sound disease control strategy[13].

The two refinements are as follows. The first is that, to be counted as entrepreneurial opportunities, the new goods, services, raw materials, and organizing methods need not always be sold or lead to new sales, only to value gains for the innovator who pursues them: a car manufacturer that responds to rising oil prices and stricter environmental regulations by developing new fuel-saving technologies is certainly seizing an emergent entrepreneurial opportunity, even if it doesn't sell the technology to anyone else, or if this doesn't lead to the sale of more cars, as the value gains from the innovation may also come from, say, an increase in the profit margin for each car sold. The second is that, when the entrepreneurial agent is the state or some other actor (theoretically) interested in social welfare rather than private gains (such as an NGO), the definition of *value gains* may need to be extended to fit what *these* particular actors value. Thus if, say, the state senses an unmet demand for cultural enrichment and starts building and running libraries, and for social welfare reasons decides to charge an entry fee that doesn't cover the investment and operational costs that this involves, we need not say that it is not seizing an entrepreneurial opportunity: though the library ventures run at a financial loss, the social welfare gains they generate may well be greater than the costs. These two refinements make room for phenomena such as state entrepreneurship (Mazzucato, 2013) and within-the-firm entrepreneurship (Antoncic and Hisrich, 2003), which can sometimes be very significant.

Attractive Opportunities May Stay Undiscovered

In the absence of disequilibrating forces, the academic argument made by general competitive equilibrium analysis suggests economic systems will reach an equilibrium where entrepreneurial opportunities will tend to vanish (Shane and Venkataraman, 2000).

[13] In this last case, however, it may not be desirable from a social welfare point of view for the entrepreneur to appropriate the returns from the innovation, as this may lead to the exclusion of others from using the strategy, or to making it too expensive. This shows how it is not necessarily desirable, from a social welfare point of view, for all entrepreneurial opportunities to be pursued, as pointed by Baumol's in his reflections about productive, unproductive and destructive entrepreneurship (Baumol, 1996).

However, as Schumpeter (1934) noted long ago, economic systems are never really in equilibrium, so the argument is *really* academic. As a result of this perennial disequilibria, new entrepreneurial opportunities are constantly being created, and old ones are endlessly vanishing or being exhausted. But although the successful development of a new sector is proof that, as the sector was just emerging, there were worthwhile opportunities available to be seized, the nonexistence of a sector is no proof that there weren't or there aren't: if no one rises to the challenge, the water thirsty mining sector that sits in the middle of the desert may stay thirsty for long, but that doesn't mean the opportunity is not there to be seized. As Hausmann and Rodrik (2003) argue, there is no reason to believe that all opportunities will be seized before they vanish, and even less reason to believe that they will be seized as soon as they emerge. The universe of available entrepreneurial opportunities is always greater than the subset that are actually seized by someone. But like the one of the physicists, this universe is not boundless. Not every potential innovation can lead to gains in value that are greater than the costs incurred to bring it about, and thus not every potential innovation is a worthwhile entrepreneurial opportunity: though the growth of a water thirsty mining sector may turn water-saving innovations into excellent entrepreneurial opportunities, it may not make labor-saving innovations much more attractive opportunities, as the sector may already be largely automated.

As a Sector Develops, its Underpinning Opportunities Change

It is important to note that the very process of development of a new sector, as it progresses, can and usually does considerably alter the opportunities that underpinned its earlier stages of development. The first firm to offer paid Internet access services in economies that do not have these will, perhaps, benefit from advantages such as being a monopoly and being recognised as the pioneers in the activity. This first mover, however, will also likely be hindered by disadvantages such as people's unfamiliarity with these services and the non-existence of an ancillary services sector that they can outsource non-critical tasks to. Latecomers, on the other hand, may not benefit from a monopoly position or early brand recognition, but can start with much better information about the market and need not waste time and resources developing capabilities for non-critical tasks, among other advantages that latecomers can often benefit from (Soete, 1985; Steinmueller, 2001). There is thus a difference to be made among the factors that affect the allure of a sector's underpinning entrepreneurial opportunities *before* its emergence process takes off, and the factors that influence these opportunities *after* this take-off has happened and the effect of these and other kinds of feedbacks start to be felt (e.g. Azariadis and Drazen, 1990; Greenwald and Stiglitz, 1986; Henderson, 1997; Katz and Shapiro, 1994; Moretti, 2004).

The Sources of Opportunities and the Main Structural Change Drivers

A big part of understanding how new sectors develop is to understand how the entrepreneurial opportunities that underpin their emergence processes come about. A common view about the matter is that held by Kirzner, who writes that such opportunities come from 'the absence of full adjustment between input and output markets' (Kirzner, 1997). But though this view has some truth to it, it is so succinct that it doesn't really say much and, moreover, leads to the question of how those maladjustments originate: rising tomato prices may present an inviting opportunity for small flexible farms, but why does the price of tomatoes change in the first place? It is fair to say that Kirzner himself provides part of the answer: in the last analysis, new entrepreneurial opportunities originate in 'ceaselessly changing tastes, resource availabilities, and known technological possibilities' (1997, p. 70) – all factors that introduce Knightian uncertainty (Knight, 1912) into economic systems and make it difficult to predict what will tomorrow's opportunities be like. Similarly, Kuznets had stated in 1973 that 'given the differential impact of technological innovations …, the differing income elasticity of domestic demand …, and the changing comparative advantage in foreign trade', 'rapid changes in production are inevitable' (Kuznets, 1973, p. 250), thus echoing two of Kirzner's sources of new opportunities and adding one more. Yet what these authors point to does not exhaust all of the possibilities: entrepreneurial opportunities may also originate in evolving policies (e.g. Gerard and Lave, 2005), institutions (Acemoglu and Robinson, 2013; Baumol, 1996), and more generally from any turn, force or pressure that brings change to an economic system.

The potential sources of new entrepreneurial opportunities are not just varied: they are also inter-related and add up. Entrepreneurial opportunities are the outcome of prolonged and complex processes of structural change, and they always come as a result of the confluence of many factors, many of which have origins that may largely predate the appearance of any specific opportunity: the opportunity to start a smartphone-app-based tourist guide service business may seem to come from the advent of smartphones, but before smartphones was the Internet, before the Internet transistors, before transistors tourism, and so on. For any given opportunity, however, one can typically identify some sources that are more recent and/or relevant than others. Understanding the sources of an entrepreneurial opportunity is thus a selective undertaking, one that must, by necessity, focus on the most recent and the most significant factors, whatever the criteria for recent and significant are. And although these sources can vary wildly, the broad, overlapping, and inter-related categories that we've highlighted in this and the previous chapters – technical change, changing consumption preferences, fluctuating resource availabilities, and evolving policies and institutions – are widely held to cover much and perhaps most of the terrain.

The Sources of Opportunities: Two Contrasts

There are at least two contrasts with academic and policy relevance that one may make when inquiring about the sources of any given kind of entrepreneurial opportunity. The first of these is that which can be done between internal developments – such as the passing of laws, the change of tastes, or the growth of population – and external influences – such as wars, the growth of export markets, or the development of new technologies by trade partners. The contrast feeds into the debate about the extent to which (and the way in which) the lower-complexity countries *should* open themselves to the world as an economic development strategy, and also into the related debate about the extent to which (and the way in which) external influences *can* become sources of new entrepreneurial opportunities in these countries. Making room for the internal developments vs. external influences distinction in our framework will enable us to engage with these key issues of the economic development literature (Amsden, 2001; Chang, 2002; Friedman, 2007; Lall and Narula, 2006; Stiglitz, 2007).

The second contrast links to the debate about the extent to which innovation is driven by *demand-pull* factors – such as the passing of regulation that allows self-driving cars to be on the streets – versus *technology-push* factors – such as the development of more accurate image-processing technology that these cars can use to drive more safely. In this regard, one may ask whether the factors that drove some infrastructure sector innovation to become attractive enough to grant the development of a new sector were of the demand-pull or technology-push types. This feeds into the academic debate about the matter, and is policy-relevant because the debate informs the design of innovation policies that seek to strike the right balance between demand-pull and technology-push instruments. Since (Dosi, 1982b), a common view of the matter is that technology-push factors tend to drive the more discontinuous or 'radical' kind of innovation, while demand-pull factors tend to drive incremental innovation. Later work, however, has shown how this broad view is accurate only as a very first and high-level simplification. When researchers have looked more closely, they have found that both factors tend to matter, that they interact, and that their effect is mediated by a long list of other factors including flows of knowledge between sectors (Rosenberg, 1994), technological opportunities (Jaffe, 1986; Klevorick et al., 1995), absorptive capacity (Cohen and Levinthal, 1990; Mowery, 1983; Rosenberg, 1990), and capabilities (Di Stefano et al., 2012; Nemet, 2009). Most of these findings, however, come from studies about new-to-the-world, manufacturing-related innovation undertaken in advanced economy contexts. Therefore, it is of interest to explore their applicability to new-to-the-country infrastructure innovation in lower-complexity economies – which is what we will do.

It is important to note that this second contrast does not encompass all of the ways in which innovation may be spurred from the supply-side. Although innovation may be driven by *technology-push* factors, it may also be driven what Nelson and Winter have called *capabilities-push* factors (1977). Supply-push drivers of innovation would thus include technology-push factors, but also capabilities-push factors. Taking, say, the personal computer as the target innovation, a rapid decrease in the cost of integrated circuits due to a scientific discovery would count as a technology-push factor, while a rapid increase in the availability of electrical engineering training programs would count as a capabilities-push factor. While this broader scheme is valid, it is important to understand how it fits within our framework. Factors that strengthen the entrepreneurial function and/or ease entrepreneurial agents' access to what capabilities they require to pursue entrepreneurial opportunities will for us count as innovation drivers of the capabilities-push kind. We will, therefore, not treat capability-push drivers as if their effect was to increase the allure of entrepreneurial opportunities, but rather as if their effect was to increase the ability of economic agents to pursue them. Capabilities-push drivers will thus be treated in the discussions about the entrepreneurial function and access to capabilities, and not in the discussion about entrepreneurial opportunities.

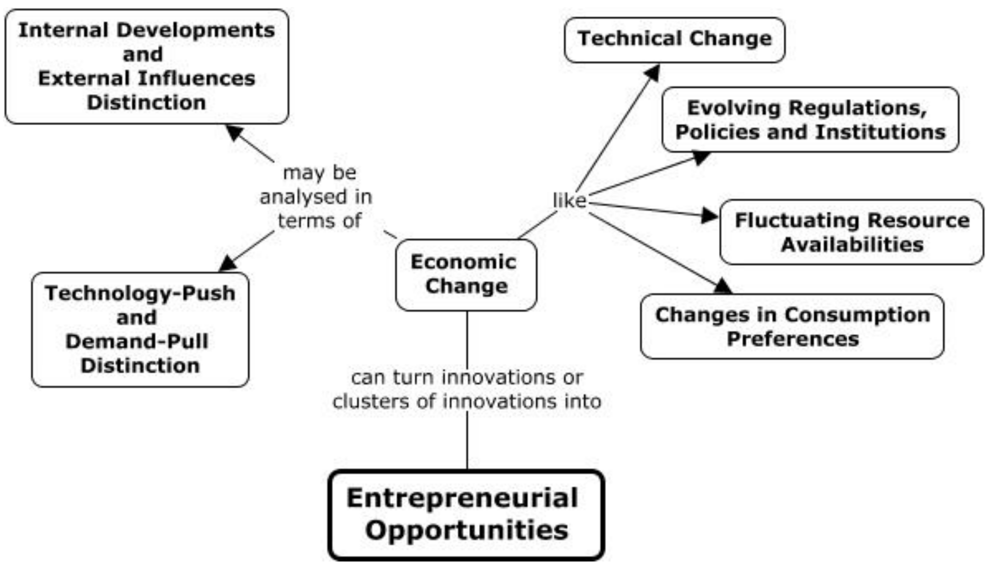

Figure 3.2: Concept map of the elements of the framework relating to entrepreneurial opportunities. *Not all potential innovations are entrepreneurial opportunities, but economic change can make them be so. The literature suggests technical change, changes in consumption preferences, fluctuating resource availabilities, and evolving policies and institutions as the factors that most commonly turn potential innovations into entrepreneurial opportunities. Sources of new opportunities may also be analysed in terms of the internal developments vs. external influences, and technology-push vs. demand-pull contrasts. But neither these distinctions, nor the four aforementioned 'usual suspects', cover all of the possible sources of new opportunities.*

3.1.3. The Entrepreneurial Function

As Hausmann and Rodrik (2003) note, the mere existence of attractive entrepreneurial opportunities is no guarantee that new sectors underpinned by them will develop. For this to happen, individuals and organisations – usually firms, but not necessarily – must pursue these opportunities. The pursuance of new entrepreneurial opportunities is widely held to be the main function of entrepreneurship – or the main *entrepreneurial function* – and is usually distinguished from other kinds of economic activity. Chandler, for example, distinguishes among the 'entrepreneurial function' and the 'administrative function' of the headquarters unit in large multi-business firms: the former, he argues, involves value-creation, and the latter loss-prevention (Chandler, 1991). Lumpkin and Dess (1996), for their part, distinguish among firms that have an 'entrepreneurial orientation' from those that do not, arguing that the former are characterised by autonomy, innovativeness, risk taking, proactiveness, and competitive aggressiveness. Kirzner, another prominent writer in this field, argues that the main function of entrepreneurship is to discover or 'grasp the opportunities for pure entrepreneurial profit created by the temporary absence of full adjustment between input and output markets' – which in his view requires boldness, imagination and drive (Kirzner, 1997). And Leibenstein, who looks at the matter from an economic development perspective, highlights the fact that, to be able to successfully pursue new entrepreneurial opportunities, entrepreneurs must be 'capable of making up for market deficiencies' and become 'input completers', showing again how scholars conceive of entrepreneurship as a distinct kind of economic activity (Leibenstein, 1968).

Building on this, we may, for our purposes, define the entrepreneurial function as the pursuance of unexploited entrepreneurial opportunities. And we may also distinguish the economic agents that contribute to this function – the *entrepreneurial agents* – from those that undertake *support activities*, i.e. activities that may also be important for the pursuance of such opportunities but that don't entail the same degree of innovativeness, risk taking and proactiveness in relation to them. It is important to note that the opportunities need not always be new-to-the-world innovations, nor even new-to-the-country innovations. Although pursuing these would certainly be entrepreneurial activity, our definition of the entrepreneurial function is broader, encompassing the introduction of innovations in all sorts of new contexts, and not just in global or national contexts.

In Infrastructure Sectors, The Entrepreneurial Function has Two Parts

What the entrepreneurial function involves can greatly vary depending on the kind of opportunities that are involved. If, say, the opportunity entails the introduction of a new-to-the-world kind of consumer product, like a smartphone or a drug, the entrepreneurial function may be said to involve *discovering* a latent demand, *designing* a product that fulfils it, *manufacturing* the product, and *marketing* it. But if the opportunity entails the introduction of a new-to-the-country import, the function may only involve *discovering* the latent demand, *opening new trade channels* and *marketing*. If the opportunity is about the introduction of a new business management practice – such as, say, the 'business model canvas' method – the function may involve *designing* the new management practice, *developing capabilities to offer consultancy services* based on this practice, and *marketing*. And if it is about the introduction of a school teaching innovation, it may involve the *development of capabilities to train teachers*, and again *marketing*. In all of these cases, the individuals and organisations that contribute to the entrepreneurial function may only be active in some of these areas, and may relate to other entrepreneurial agents in complex ways. By way of example, it is common for ICT innovations to begin their life within small start-up firms that *discover* a latent need and *develop* an ICT service that fulfils the need. Often, these firms are then acquired by giants, such as Google or Facebook, that *scale* and *market* the service. But in other cases, these giants, or other competitors, reproduce the innovation by themselves, and then scale and market it, preventing the first-moving innovator from appropriating the returns to its innovation. Google and Facebook, however, also engage in their own *discovery* and *development* of new opportunities, in addition to *scaling* and *marketing* those discovered and developed by someone else. Thus, the entrepreneurial function involves different things for different kinds of entrepreneurial opportunities. And the nature of the contribution that different entrepreneurial agents make to it is not always the same – or brings the same rewards.

In the case of new-to-the-country infrastructure sectors that concern us, the pursuance of the underpinning opportunities calls for the design, construction and operation of novel infrastructure facilities for the provision of certain infrastructure services to a particular user or group of users. As we'll see, it will prove fruitful to divide the corresponding entrepreneurial function into two sub-functions or parts (what follows builds mainly on Bell, 2007; Brealey et al., 1996; Khatib, 2003; and Kirzner, 1997). The first part of the entrepreneurial function in infrastructure sectors involves *discovering* specific project opportunities (i.e. locations and contexts where the building of the facilities could be valuable – valuable enough, that is, to justify their construction) and *developing* these opportunities into viable investment projects (which, depending on the kind of facility, may involve carrying out different sorts of technical and economic feasibility studies, drawing up conceptual, basic and sometimes detailed engineering designs, acquiring permits, negotiating land-lease and other kinds of contracts, and so on). For example, if one traces the history of a large irrigation project, one will likely find that, at some point, the latent need for the project was identified by an entrepreneurial agent – for these kinds of projects, often the state – and was then developed into an investment project consisting of geological and hydraulic studies; blueprints detailing the dams, channels, gates, and other such parts of the scheme; studies about the costs of construction and the economic gains expected from the project; de facto and de jure agreements among the project's stakeholders; and so on and so forth.

The second part of the entrepreneurial function in infrastructure sectors involves *sponsoring and financing* these projects. Normally, this entails formulating a business model that ensures the sustainability of the planned investments; making the decision to go ahead with them; procuring the financial resources necessary to pay for their construction; coordinating and seeing things through until the facilities are operational; and taking control of their management and operation once they are. In infrastructure sectors, the entrepreneurial function thus involves *discovering and developing* specific project opportunities into viable investment projects, and *sponsoring and financing* these projects. In line with common usage, we may call *project developer (developer)* to the agent that leads or oversees the activities of the first part of the function, and *project sponsor (sponsor)* to the agent that leads or oversees the activities of the second part. Among other things, this division is useful because – as we will see later – it is often different entrepreneurial agents that contribute to these two parts of the function.

Our inquiry about the entrepreneurial function in infrastructure sectors will focus on two of its aspects. The first of these aspects involves the different kinds of entrepreneurial agents that may contribute to it. Regarding this first aspect, we will distinguish agents according to whether they are incumbents or new entrants, and whether they are foreign or domestic. The second aspect involves the different kinds of contribution that entrepreneurial agents may make to the function. Regarding this second aspect, we will distinguish between the contribution made by project developers and that made by project sponsors, and between the different character of the contribution made by project developers when these are independent, consultant, or self-developers.

Different Kinds of Entrepreneurial Agents may Contribute to the Function

As we saw, the development of a new sector is always part of the process of transformation of a more broadly defined sector. Therefore, for any given sectoral emergence process, we can identify the broader sector of which the process is part, and inquire about whether it was the *incumbents* of this broader sector, or *new entrants*, that made the largest contribution to the entrepreneurial function[14]. According to technological regime theory, which was introduced in Chapter 2, new entrants are more likely to dominate when a sector's technological regime is characterised by high technological opportunities, low appropriability conditions, low cumulativeness conditions, and a scientific knowledge base. And incumbents are more likely to dominate when the regime is characterised by low opportunities, high appropriability, high cumulativeness, and a technological knowledge base (Breschi et al., 2000; Malerba, 2007; Malerba and Orsenigo, 1993). New entrants, research also suggests, have advantages over incumbents in the more radical kinds of innovation (Christensen, 1997). By distinguishing, in our inquiry, between incumbent and new entrant entrepreneurial agents, we will be able to discuss the extent to which technological regime theory – which mainly originated in studies of manufacturing sectors in advanced economies – applies to infrastructure sectors in lower-complexity economies.

In addition to the above, research also suggests that whether it is incumbents or new entrants that dominate innovative activity will depend on the nature of a sector's demand. Several features of demand have been linked to innovative behaviour. One of these are the so-called network externalities: when the attractiveness of products or services grows as more users adopt the same variant of them – as happens with the telephone or Facebook – the incumbents that offer the variant that first becomes dominant are unlikely to be displaced by new entrants (Shy, 1996; Windrum and Birchenhall, 2005). Another are bandwagon effects: when the quality of new products or services is hard to assess – as happens with laptop computers and many foodstuffs – users may decide which variants to buy based on what other users have chosen, giving the incumbents – who may encourage the effect through advertising – an advantage over new entrants (Sutton, 1991). A third is the degree of heterogeneity of demand: when the needs of users are diverse – as happens with software users – new entrants are more likely to survive, as they will be able to exploit niches overlooked by incumbents (Adner, 2002). And a fourth, which is a variant of demand

[14] Thus if, say, the inquiry were about the emergence of a wine producing sector, we would call the established agro-industrial firms the incumbents, and everyone else the new entrants; and if it were about the emergence of a lithium mining sector, we would call the established copper, silver, molybdenum, rare earths or other established mining firms the incumbents, and other firms the new entrants.

heterogeneity, is the presence of experimental users: when experimental users are interested in trying new products or services – even if they are inferior – because of the 'intrinsic merit' of their embodying a new technology – as NASA and computer geeks often do – new entrants producing them are more likely to survive, as income from these niches will enable them to improve innovations until they reach their full potential (Malerba et al., 2007). Similarly, we may expect differences in the nature of the demand for what different infrastructure sectors provide to influence this aspect of their pattern of entrepreneurial activity.

In addition to the distinction between incumbent and new entrants, we may also distinguish between the contributions to the entrepreneurial function made by *domestic* and *foreign* entrepreneurial agents. On this matter, research suggests that the likelihood of multinational enterprises (MNEs[15]) making a substantive contribution to the function by channelling FDI into a new sectoral development process depends on a number of different factors. These factors include, but are not limited to, the availability of natural resources (McKern, 1993), the degree of development of human capital (Noorbakhsh et al., 2001), the level of absorptive capacity (Fu, 2008), the size of the potential market (Jaumotte, 2004), the wage level (Cheng and Stough, 2006; Kersan-Skabic and Orlic, 2007), and the quality of the country's institutions (Asiedu, 2006; Busse and Hefeker, 2007). While some factors, such as institutional stability and absorptive capacity, tend to be transversal, others tend to affect specific kinds of FDI only. Thus, Schneider suggests dividing FDI into 'resource-seeking', 'market-seeking' and 'efficiency-seeking', and argues that the extent to which a location will attract each of these will depend, respectively, on resource availabilities, market size, and production factor prices – especially wages (Schneider, 2013).

Distinguishing among domestic and foreign contributions to the entrepreneurial function will enable us to engage with the aforementioned literature on the determinants of the scale and the direction of FDI. However, and perhaps more importantly, making this distinction will also enable us to engage with the more general discussion about the feasibility, convenience and consequences of an FDI-assisted economic development strategy (Amsden, 2001; Chang, 2002; Friedman, 2007; Lall and Narula, 2006; Stiglitz, 2007). Two crucial questions within this discussion are whether MNEs and FDI crowd out domestic firms and domestic investment (Agosin and Machado, 2005; Amsden, 2009), and whether these generate knowledge spillover effects (Crespo and Fontoura, 2007). On both

[15] We will speak of multinational enterprises (MNEs) rather than multinational corporations (MNCs), as this latter term implies relatively large firms, and excludes smaller but still multinational foreign firms.

cases, arguably, the only clear result coming from many years of research is that there is not a single answer to either of these questions: FDI and MNEs may, or may not, generate crowding-out effects and knowledge spillover effects, depending on a number of factors. For years, economic development researchers have tried to understand these factors by asking which kinds of country (e.g. lower or middle-income), which kinds of FDI (e.g. resource-seeking, market-seeking, or efficiency-seeking), and which kinds of policies (e.g. trade agreements or local content requirements) are more or less likely to generate crowding-out and knowledge spillover effects. However, Marin and Bell have shown that it is not just country- or sectoral-level contingencies, but also firm-level specificities, that determine the degree to which these effects are generated (Marin and Bell, 2010, 2006).

Transactions and the Nature of the Contributions

Apart from the kinds of economic agent that contribute to the entrepreneurial function, one more area in which we will focus is the different *nature* of the contributions that these agents may make. As we've seen, the function, in infrastructure sectors, may be divided into two parts: a) the discovery of specific entrepreneurial opportunities and their development into viable investment projects; and b) the sponsoring and financing of these projects. When referring to the nature of an agent's contribution to the function, what we will be referring to is to a) whether the agent contributes to one, to the other, or to both of these parts of the function; and b) how it relates to other economic agents as it does so. Contributions of different natures, as we will see in Chapter 5, are not equally significant and have different implications.

To a large extent, the second of these two aspects of the nature of agents' contribution to the function (the way they relate to other economic agents as they make their contribution) is a matter of the division of entrepreneurial labour within a sector. As such, it can be informed by transaction costs theory, which offers some explanations about why firms divide labour in the way they do (Williamson, 2000). In this theory, the main unit of analysis is the transaction, defined as what takes place 'when a good or service is transferred across a technologically separable interface' (Williamson, 1981, p. 552). When it comes to the lifecycle of an infrastructure facility, one may identify two key transactions. The first is the transaction that takes place among a) the user of the infrastructure services provided by a facility, and b) the sponsor of the facility, which is the infrastructure service provider (*sponsor>user transaction*). And the second is the transaction that takes place among a) the developer of an infrastructure project, and b) the project sponsor (*developer>sponsor transaction*). In this second case, the analytical abstraction makes sense because most infrastructure projects go through two often easily distinguishable stages, which we may call the *development stage* and the *investment stage* (Khatib, 2003, pp. 22–28). These two stages, which correspond to the two parts of the entrepreneurial function in infrastructure sectors, are technologically separable and may, therefore, be undertaken by different economic agents – which is why it makes sense to abstract the transition from one to another as a transaction between two analytically distinct parties: the developer and the sponsor.

In transaction costs theory, transactions may take place in terms of three different modes of governance[16]: *market governance*, where the transaction takes place in the marketplace without the drawing of a transaction-specific contract; *contractual governance (trilateral or bilateral)*, where the parties to the transaction enter into an elaborate transaction-specific contract devised to regulate their relation; and *unitary governance*, where the transaction takes place within a single organization and not among two distinct parties. For our purposes, these three modes of governance may be thought of as a continuum going from market governance, passing through contractual governance, and finishing in unitary governance (Williamson, 1981, 1979).

According to the theory, transactions may be characterised along a number of dimensions that influence which of these modes of governance is favoured. One of these is their *uncertainty*, which may be defined as the ease with which the parties to the transaction can evaluate the quality or value of what they'll receive *ex-ante*, i.e. before the transaction takes place (for example, the acquisition of a ton of steel has low uncertainty, while the purchase of a start-up firm by a larger firm has high uncertainty). A second is their *frequency*, i.e. whether the transaction is one-off (such as the aforementioned acquisition of a start-up by a larger firm), occasional (such as the procurement of capital goods by a manufacturer) or frequent (such as the distribution of goods to a wholesaler). And a third is their *asset specificity*, which may be defined as the extent to which the transactions require transaction-specific investments that lose their value if the transactions do not take place (such as a bespoke software platform that supports the procurement of an uncommon business service) (Williamson, 1981, 1979).

In general, the potential for the realisation of economies of scale is a force that gives an advantage to specialisation, and hence to market transactions with third-parties producing at scale rather than to in-house production of any required good or service

[16] What follows is a simplified account of the theory, one that fits our purposes without going into unnecessary details.

(market governance). Market transactions, however, are always open to opportunistic behaviour by either of the parties. If the transactions are not uncertain, this risk is low. But if they do have a significant level of uncertainty, then this risk may be considerable, adding to the transaction costs, and thus making contractual and unitary governance more attractive. Transaction costs will also increase if the transactions are highly asset specific, for, in these cases, opportunistic behaviour leading to the severance of the relation between the parties will lower the value of the transactions-specific investments that they had to make to support their transactions. Hence, high asset specificity favours unitary or at least contractual governance. The risk of opportunistic behaviour, and therefore the transaction costs, also increase when transactions are not frequent, for opportunistic behaviour would undermine the trust that needs to be nurtured to sustain long-term relationships. Hence, transaction infrequency would also tend to favour unitary or contractual governance. However, transaction infrequency may also play in the opposite direction: if the set-up costs of a transaction – i.e. the investments that need to be made in order to develop the capability to make, rather than buy, a product or service – are too high, then they may only be justified if the transaction is going to take place frequently (Williamson, 1981, 1979).

Earlier Contributions are More Important than Later Contributions

The last point to make about the nature of agents' contribution to the function concerns the relation among the timing of this contribution and its significance. It has long been known that economic activity in general, and innovation in particular, shows bandwagon effects: once an economic agent has successfully introduced an innovation, others are often quick to follow (Freeman and Perez, 1988; Perez, 1983; Robertson, 1967; Schumpeter, 1939). Although the followers can often do better than the first movers in terms of market shares and profitability, the contribution to the entrepreneurial function of the first movers has an intrinsic value which that of latecomers doesn't, for pursuing untried kinds of entrepreneurial opportunities is both more difficult and riskier than pursuing opportunities that have been tried before. Thus, the first to start, say, a novel aquaculture venture, can't be entirely sure about the costs of setting it up and operating it, how best to organize it, and whether there will be a market for the produce; those who decide to follow, on the other hand, will be able to learn from this first mover and make better-informed decisions about these and other such matters. Therefore, all other things being equal, earlier contributions to the entrepreneurial function are more valuable than later contributions, as these – to the extent that they uncover attractive and novel opportunities – show the way for others to follow (Hausmann and Rodrik, 2003).

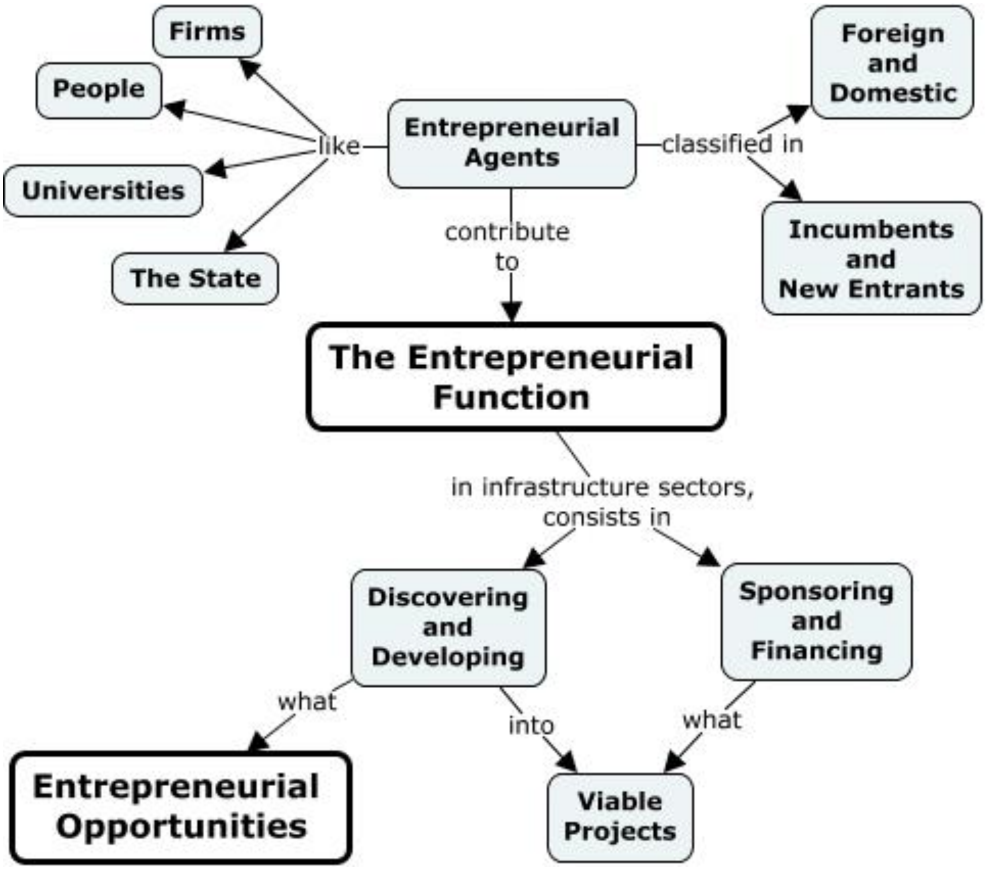

Figure 3.3: Concept map of the elements of the framework relating to the entrepreneurial function. *Entrepreneurial agents of different kinds, which may be characterised along the foreign/domestic and incumbent/new entrant divides, contribute to the entrepreneurial function. In infrastructure sectors, the entrepreneurial function consists in discovering and developing specific infrastructure project opportunities into viable projects, and in sponsoring and arranging finance for those projects.*

3.1.4. Capabilities

As Dosi et al. (2001) note, it is useful to make a distinction between the *intention* to pursue an entrepreneurial opportunity and the *ability* to do so. As these and other authors do, we will call *capabilities* to what fills 'the gap between intention and outcome' (Ibid.). But what are capabilities composed of? Bell distinguishes among four *components of capabilities*: *physical capital*, *knowledge capital*, and *human capital,* and *organisational capital* (Bell, 2009). To exemplify these, let us look again at the entrepreneurial opportunity represented by the water thirsty mining sector, and let us imagine that a firm plans to pursue this opportunity by desalinating water from the coast and pumping this water to the various mining operations, charging a fee for this. In order to implement this solution, the firm needs, first of all, to be able to access several different kinds of *physical capital*: pumps, filters, pipes, valves, controls, etc. Second, it needs to be able to access several kinds of *knowledge capital*: topographic maps of the zone where the scheme will be constructed, scientific and technical literature about the different water desalination techniques, user guides for the various hardware equipment, etc. Third, it needs to be able to access people with knowledge and skills relevant to the design, construction and operation of the scheme, i.e. the managers, engineers, technicians, etc. whose abilities, when hired by the firm, constitute its *human capital*. And fourth, it needs to be able to benefit from several different forms of *organisational capital*, including that represented by the firm itself as an organisational unit, with all its routines, practices, shared beliefs, goals, etc.; that represented by its ties with other firms; and so on and so forth. The ability to access or benefit from these various forms of capital – either by accumulating it within the firm or by accessing or benefiting from external sources of it – is what gives the firm the capability to implement the desalinated sea water solution, and in this way seize the entrepreneurial opportunity that originated in the mining sector.

Capabilities are Built on Many Layers of Capital Held at Various Levels

The specific forms of physical, knowledge, human, and organisational capital just mentioned, however, barely scratch the surface of what is needed to implement the solution in the example. There are broader forms of each of these four kinds of capital that may not be as directly related to this particular solution as those mentioned above, but which are equally needed: the electricity provision infrastructure, say, which will power the pumps and the desalination plant (physical capital); the broader bodies of scientific and technical knowledge which underpin the various water desalination processes (knowledge capital); the knowledge and skills of the people that work at the numerous organizations – partner firms, municipalities, other government bodies, universities, etc. – with which the firm will have to liaise to implement the solution (human capital); and the body of laws that regulate the construction of pipelines and other such relevant matters (organizational capital). The example shows the convenience of thinking about capabilities as cumulative and to some extent multi-purpose building blocks, as the LEGO bricks that Hidalgo and Hausmann compare them to (Hidalgo and Hausmann, 2009). And it also shows the usefulness of conceiving of them as a *multi-level* phenomenon, such that one may distinguish among the various components of capabilities at the firm, sectoral, country, and external levels (Archibugi and Coco, 2005; Dosi et al., 2001; Lall, 1992). We can think of the physical and knowledge capital owned by a firm, along with the skills of its staff and its organisational routines, practices, shared assumptions and goals, as what the firm contributes to its own and – to the extent that it relates to the wider economy – others' capabilities. Capital of whatever sort that cannot be pinpointed to any particular firm, and which is of particular usefulness to one specific sector, is what we may think of as the sectoral component of the capabilities of its constituents. This would include, say, shared sector-specific facilities (i.e. the common infrastructure of, say, a biotechnology cluster), shared organisational arrangements (i.e. the management of the cluster, professional associations, etc.), sector-specific codified knowledge, laws and regulations; and so on and so forth. More broadly useful forms of capital – such as roads and general transportation infrastructure, the education system, general laws, etc. – is, in turn, the country-level component of the capabilities of its economic agents. Thus, what any specific economic agent can do – its capabilities – stems from its ability to access or benefit from capital held at various levels.

Delimitating the Capability Development Process of a Sector

One may expect new sector development processes to be accompanied by associated capability development processes. Understanding these latter would be an important part of understanding the former. The development of capabilities, however, is continuous and messy, and it is therefore difficult to draw a line separating the capability accumulation process of a sector from that of the rest of the economy. The development of new capabilities, moreover, is a regular source of new kinds of entrepreneurial opportunities, which adds to the problem: as a sector accumulates physical, knowledge, organizational and human capital, it may start requiring novel inputs from other sectors, and it may become able to offer novel output to yet some more, turning previously unattractive entrepreneurial opportunities into more attractive ones. However, if the analysis is not to get entangled by mixing the processes that give rise to new entrepreneurial opportunities with the processes that the pursuance of these opportunities set in motion, the line that separates the capability development process of a sector from that of the rest of the economy must somehow be drawn.

In this study, what we will do is to draw this line by making a distinction between physical, knowledge, human, and organisational *capital which is accumulated with the intention of pursuing the opportunities that underpin a sector*, and *capital which is accumulated for other purposes*, even if it ends up benefiting the sector. When the case is the former, we will say that the process of accumulation of capabilities is part of the process of emergence of the sector. And when the case is the latter, we will say that it is one of the sources of the sector's entrepreneurial opportunities. Thus – using again the example of the water thirsty mining sector – we *would not consider*, say, the development of the electricity transmission infrastructure, or of the country's education system, capability accumulation processes that are part of the process of emergence of the eventual desalinated water provision sector, even if they have an impact on it by contributing to the allure of its underpinning opportunities. But we *would consider*, say, the accumulation of all sorts of capital related to these opportunities by the firms of the sector, or the creation of a sectoral association, to be part of the process of emergence of the sector.

Different Kinds of Capabilities

As we saw in the previous chapter, it is often said that capability accumulation processes tend follow certain recognizable sequences, best thought of as ladders with rungs of increasing complexity that can only be traversed one step at a time, with different authors proposing different ways of conceiving of these ladders depending on the goals of their research (Bell, 2006; Figueiredo, 2003; Katz, 1997, 1984; Mayer, 1996). In our case, it will be useful to follow Amsden and conceive of this ladder as having three steps: first, *production capabilities*, broadly defined by Amsden as 'the skills necessary to transform inputs into outputs'; then, *project execution capabilities*, defined as 'the skills necessary to expand capacity'; and, finally, *innovation capabilities*, defined as 'the skills necessary to design entirely new products and processes' (Amsden, 2001; Amsden and Hikino, 1994). Although, in her definitions, Amsden only refers to skills (human capital), we can expand them to include the other forms of capital that, following (Bell, 2009), compose capabilities as we've defined them. Having said this, it is useful to note that the kind of development processes we will be looking at *do not* require a great deal of innovation capabilities as defined above (notwithstanding that other authors would likely disagree with Amsden's naming scheme, which makes it look like there can be no innovation in production and capacity expansion, see Bell and Pavitt, 1997): for the most part, they require production and project execution capabilities.

We've seen above how capabilities are what fills 'the gap between intention and outcome' (Dosi et al., 2001). Now, all complex economic outcomes require the completion of a number of more simple *tasks*, and these tasks may be characterised according to the degree of *technical* vs. *managerial* skills needed to complete them. In line with previous research (e.g. Cassiolato and Baptista, 1996; Figueiredo, 2002; Iammarino et al., 2008), we will call *technological capabilities* to the capabilities needed to complete tasks which are more technical in nature, and *non-technological capabilities* to the capabilities required to complete non-technical – but often equally crucial – tasks. Following Bell (2007), we will moreover divide technological capabilities in *production capabilities* (capabilities to operate technical production systems), *design and engineering capabilities* (capabilities to use existing technical knowledge to design or transform technical production systems), and

R&D capabilities (capabilities to create new technical knowledge). These three categories parallel Amsden's production, project execution and innovation capabilities, but they are different because her scheme merges technological and non-technological capabilities. Technological capabilities, as we saw, are often deemed to be both the most difficult to develop within the domestic economy and the most crucial to develop for catching up with the more advanced countries (Bell, 2009; Bell and Pavitt, 1997, 1995; Perez, 2010; Perez and Soete, 1988; Verspagen, 1991). They are, therefore, particularly important to look at.

Capabilities, Human Capital and Foreign Skills

In the lower-complexity economies, the unavailability of human capital – i.e. of highly skilled people – often becomes the bottleneck that prevents entrepreneurial agents from developing the capabilities they need to engage in novel activities (Schneider, 2013). One possible solution to overcome skills shortages in new sector development processes is for domestic workers to develop the required skills. And another possible solution is to 'import' these skills by promoting immigration (Reitz, 2005), trading in tasks (Lanz et al., 2011), or other such means. The 'import' of skills, however, may also respond to other forces such as the desire to maintain chain of command in hierarchically organised MNEs (Schneider, 2013). And, moreover, too much 'import' of skills may lead to undesired side effects such as limited learning (Bell et al., 1982; Van Dijk and Bell, 2007) and dependent development (Evans, 1979; Katz, 1976). To understand how a new sector develops, it is, therefore, important to look at the degree to which its development relies on the skills of foreigners, and the reasons for this.

There are several conjectures that one may make about this matter based on the results of past research. First, one may conjecture that the more novel a task is to the economic agents of the domestic economy, the more likely its completion will rely on foreign skills (Boschma, 2005; Boschma et al., 2013; Hausmann et al., 2007). Second, one may expect that the easiest it is to outsource a task, the more likely one will find foreigners involved in its completion (Bhagwati et al., 2004). Third, one may predict that the later a project is completed, the more likely one will find it relied on local skills, this because the local people will then have had more time to learn (Bell, 2006). Fourth, one may foretell that the bigger a project, the more likely it relies on foreign skills, this because there is, in these cases, more to lose if the project fails, and thus sponsors may be unwilling to rely on (presumably) inexperienced local people for sensitive tasks (Hobday and Rush, 2007). And fifth, one may presume that projects where the relevant parts of the entrepreneurial function were led by domestic firms will more likely rely on local skills (Ibid.).

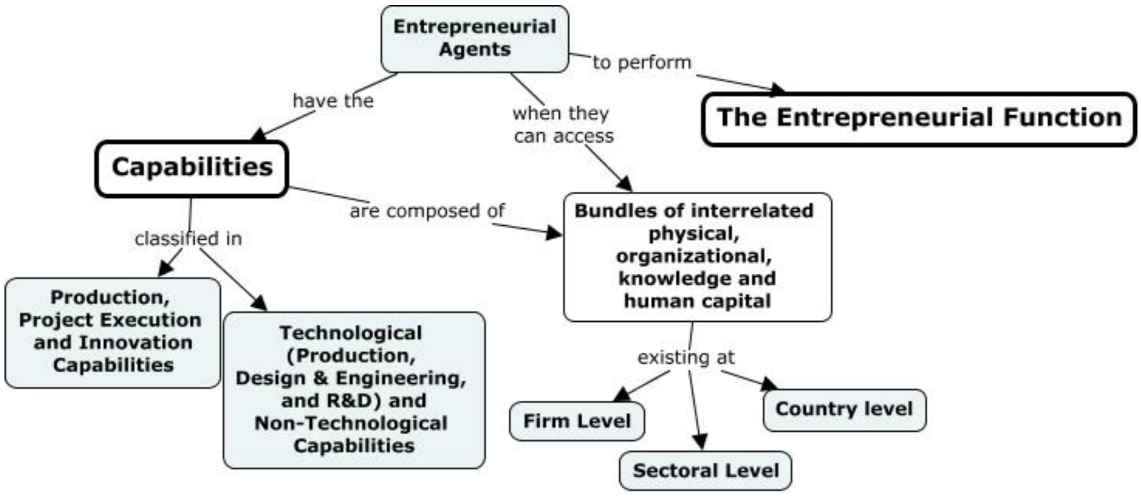

Figure 3.4: Concept map of the elements of the framework relating to capabilities. *In order to have the capabilities to perform the entrepreneurial function, entrepreneurial agents need access to bundles of interrelated physical, organisational, knowledge and human capital. Not all of this capital is attributable to specific firms (or, more generally, organisations): some is better conceived as existing at the sectoral level or the country level. Capabilities may be classified in production, project execution and innovation capabilities, and also in technological (including production, design & engineering, and R&D) and non-technological capabilities.*

3.2. Research Design

Above we saw how the development of a new sector could be conceived as a process whereby entrepreneurial agents with access to the required capabilities pursue novel entrepreneurial opportunities. As we went through the details of each of the main elements of our theoretical framework, we laid out a number of ways in which new sectoral development processes can vary, hence establishing a scheme that can be used to characterise and compare these processes. In this section, our task will be to learn how we will use this conceptual apparatus to understand better what makes the development of new *infrastructure* sectors special.

As has already been mentioned, our strategy to gain this better understanding will be to look at and compare three new sectoral development processes that took place in Chile. This, therefore, is a comparative case study piece of research (Yin, 2013). Among other things, case studies are an adequate research approach because the kinds of question that we will be addressing are open-ended ones that invite exploratory answers. In other words, although there are several theories and hypotheses about various matters which we will engage with, there is no overarching theory about how new sectors develop that we will be trying to prove or disprove: what we want is a rich description of how these processes unfold. But before going into the details about how we will get to this rich description, we must set the institutional context in which the three cases were embedded.

3.2.1. The Institutional Context

In Chapter 1, we anticipated how broad features of the economic system where a new infrastructure sector develops, such as whether the economy is an advanced one at the center of a great surge or a lower-complexity one in its periphery (Perez, 1983), will likely have a profound influence on the timing and the character of its development process. But although the advanced/lower-complexity economies divide is a useful first distinction, the diversity of the latter group – the one we are interested in – is broad enough to cast serious doubt on claims to generalizability coming from a look at just one of its members. Time and resource constraints, however, made it possible for me to do just this: look at case studies within only one country, in this case Chile. Therefore, it is now crucial to get a finer idea about the institutional features of Chile that are likely to affect any sectoral emergence process taking place within it, and also about which subset of countries from the lower-complexity group shares these features, for any claims to generalizability that we may make will have to take these into account.

A convenient way to characterise Chile's institutional setting is to introduce the framework to distinguish market economies devised by Benn Schneider (2013), which is an adaptation of the varieties of capitalism framework first proposed in (Hall and Soskice, 2001). Schneider divides market economies (MEs) into four ideal-types according to their main resource allocation mechanism: Liberal Market Economies (LMEs), where the main allocation mechanism are markets; Coordinated Market Economies (CMEs), where the main allocation mechanism is negotiation; Network Market Economies (NMEs), where the main allocation mechanism is trust; and Hierarchical Market Economies (HMEs), where the main allocation mechanism is hierarchy. The author, who specializes in research in Latin America, argues that most of the economies of this region are of this last kind, sharing similarities that make them distinct, as a group, from LMEs such as the UK and the US, CMEs such as Germany and the Netherlands, and NMEs such as Japan and Korea.

Empirically speaking, there are four key traits of HMEs (such as Chile) that distinguish them from other MEs, and which are arguably relevant to many of the issues which we'll be concerned with. The first is that, instead of the specialized high-tech firms typical of HMEs and CMEs, the largest and most important domestic firms in HMEs tend to be widely diversified business groups with subsidiaries (often dozens) in sectors (often finance, services, or low-tech manufacturing) with little 'technological or market relation to one another' (Schneider, 2013, p. 48). Most of these groups are controlled in a highly hierarchical way by a single individual or family instead of by dispersed shareholders (as in LMEs), multiple stakeholders including financiers and labour (as in CMEs), or informal business groups (as in NMEs). Crucially, these groups, which often have oligopolistic positions in the sectors they participate, finance much their growth by reinvesting profits rather than by tapping into financial markets – financial market which, compared to those of other MEs (especially LMEs), tend in these economies to be highly underdeveloped.

The second key feature that distinguishes HMEs is that multi-national enterprises typically 'constitute a third to a half of the largest firms' in them (Schneider, 2013, p. 73) – a feature which they share with LMEs but which differentiates them from HMEs and NMEs. Many of these MNEs arrived in the region through mergers and acquisitions, although greenfield FDI has not been uncommon. According to Schneider, the 'fundamental, longer-term consequence' of this high level of FDI was 'to box domestic firms out of most dynamic manufacturing sectors like electronics and automobiles' (2013, p. 82). And according to ECLAC, FDI has had 'a stronger impact as a source of financing than as a transmitter of knowledge and technology or a catalyst of structural change' (2013, p. 84). FDI, however, has had many other far-reaching consequences – good, bad and contested – in areas such as labour markets and skill levels, and there has been significant variation among different HMEs. Different countries have tended to attract different kinds of FDI. As one may have expected, resource-seeking FDI has tended to go 'where it can find natural resources' (e.g. Chile, Peru), market-seeking FDI to places with large populations (e.g. Brazil, Argentina, Mexico), and efficiency-seeking FDI to places 'near the rest of the production chain or the destination market' (e.g. Costa Rica, Mexico). Most places, however, have at least *some* degree of each kind (2013, p. 89).

A third notable characteristic of HMEs is that their labour relations tend to be highly atomised and their labour markets highly segmented. Trade union participation is exceedingly low in most HMEs (typically less than 25%), especially when compared to CMEs (where unionisation sometimes exceeds 70%). Unions, moreover, often face substantial legal or de facto restrictions that limit their scope of action (a case in point is Chile, where the law prohibits labour to negotiate at the sectoral level and to negotiate any other issue than wages). Although labor market regulations are higher than in most other MEs – a feature which points not to atomized but rather to strong labor relations –, these regulations do not apply to all kinds of employment, for much employment is informal: from about 25% in Chile, to about 65% in Peru in 2003, according to the IDB. Except for a small highly skilled labour elite, most people switch regularly from formal to informal employment during their working life. Lastly, job tenure in HMEs tends to be exceedingly low – averaging three years compared to 5 years in LMEs and 7.4 in CMEs – and switching jobs across widely different sectors is commonplace (Schneider, 2013, pp. 92–96).

The fourth critical attribute of HMEs is that they tend to be locked into a low skills trap, one where firms don't invest in high-skill-requiring activities because there are not enough highly skilled workers, and workers don't invest in acquiring high-skills because there are not sufficient high-skills jobs available. Various factors contribute to the maintenance of this equilibrium. On the demand-side, factor that contribute to the status quo are the concentration of the more complex activities of MNCs in their home countries; the displacement of the larger domestic firms from high-tech manufacturing by MNCs and foreign competition (that was accentuated after the 1990s trade liberalization); the prominence of capital-intensive economic activities related to natural resource extraction; and the high costs of firing highly skilled workers due to the high degree of labor regulations. And on the supply-side, factors that reinforce the low-skills trap include the exceedingly short job tenures and the frequent inter-industry job changes (which diminish the incentive to acquire firm-specific or sector-specific skills); the low quality of many schools, universities and other training centers; and the social exclusion, by the labor elite, of much of the population from high skills jobs based on arbitrary attributes such as race and cultural preferences (Schneider, 2013, pp. 113–128).

Although most of the above traits are shared among most HMEs, each of these economies has particularities that set them apart. As we will be looking at three sectors that developed within Chile, it makes sense to go through some of the most significant specificities of this country. More than anything, Chile stands out for its political stability and its good governance. Indicators of corruption, administrative capacity, political stability and civil service development all show Chile at the lead, often well ahead of many of its Latin American peers, and often on a par with OECD countries. Also, the country is peculiar in that its informal sector is among the smallest of the region. And also in that its domestic large diversified groups are unusually well-organized in powerful industrial associations, associations which fund influential think tanks and which actively engage in policy debates. Finally, Chile's education system has for decades been among the best in the region, and though education attainment indicators still place the country at the bottom of the OECD group, they also place it at the top of the set of Latin American HMEs (Schneider, 2013, pp. 174–181).

3.2.2. Research Questions

So far, our guiding question has been: *how do new infrastructure sectors develop?* However, as institutional differences such as those reviewed above are likely to have deep effects on the answer, is would be fitting to recognize that whatever we can learn about the process of development of new sectors by looking at three cases within one single economy – as we will do – does not necessarily apply to economies enmeshed in different institutional contexts. Hence, the question that we will be answering is a narrower one, namely: how do new infrastructure sectors develop *in HMEs?*

Having developed, in the first section, a theoretical framework to guide our inquiry, we are now in a position to state a number of more focused sub-questions. Each of these, as we will see, links to one of the three most important elements of the framework: entrepreneurial opportunities, the entrepreneurial function, and the development of capabilities.

In Section 3.1.2, we saw how entrepreneurial opportunities may owe their origins to a number of different factors. From one point of view, opportunities may originate in any combination of technical change, changing consumption preferences, fluctuating resource availabilities, and evolving policies and institutions – and perhaps too in other factors which are not as widely acknowledged as these in the structural change literature. From another point of view, opportunities may owe their origins to any combination of internal developments and external influences. And from a third point of view, opportunities may come from any combination of technology-push and supply-pull factors. One way to characterise new sectoral development processes is by inquiring about the extent to which these various factors were responsible for turning their underpinning entrepreneurial opportunities into attractive ones. In addition, we also saw that entrepreneurial opportunities need not be seized as soon as they become attractive enough to justify their pursuit: entrepreneurial agents may take long to recognise potential innovations as attractive entrepreneurial opportunities and then seize them – and they sometimes may fail to do this at all. A second interesting way to characterise new sectoral development processes is by investigating whether the innovations that underpinned these became attractive entrepreneurial opportunities long before the processes of development took off, or whether these opportunities became attractive not long before this happened. By doing this, one may judge whether the reason a sector did not develop earlier was that its underpinning opportunities were not attractive, or whether it was because of some other reason such as lack of entrepreneurship. In light of these matters, one of the sub-questions that we will seek to answer in what comes next is: *how, and when, do the entrepreneurial opportunities that underpin the development of new infrastructure sectors originate?*

In Section 3.1.3, we saw how different kinds of economic agents may be responsible for the entrepreneurial activity that needs to take place for a new sector to develop. From one perspective, a newly developing sector's entrepreneurial function may be undertaken by any combination of incumbent and new entrant entrepreneurial agents. And from another, it may be carried out by any combination of domestic and foreign agents. Characterising a new sectoral development process by sizing up the contributions of these different classes of agents is one more empirical endeavour that can further our understanding of them. As we saw, however, the contribution of these agents may not just vary in degree: it may also vary in character. One more way to gain knowledge about how new sectors develop is to inquire about the nature of different agents' contribution to the entrepreneurial function. Hence, our second sub-question will be: *what influences the kinds of economic agent that contribute to the entrepreneurial function in newly developing infrastructure sectors, and the nature of their contribution?*

In Section 3.1.4, finally, we saw how sectors may vary in the way in which entrepreneurial agents develop the capabilities that enable them to undertake the entrepreneurial function. These capabilities, recall, are built on bundles of interrelated physical, knowledge, organisational and human capital held at different levels: the firm, the sector, the country, etc. Inevitably, much of this capital will already be available to potential entrepreneurial agents before the process of development of a new sector takes off, for, in the last analysis, new capabilities are always developed on top of previously available forms of capital: no new sector develops in a blank slate. But as a sector emerges, there will normally be *a differential of previously unavailable capital* that will need to be assembled by, or somehow become available to, entrepreneurial agents for these to be able to pursue the novel entrepreneurial opportunities. Although gaining a full picture of how this differential is put in place is a desirable outcome, our inquiry about this matter will be limited to two issues. First, we will try to understand the nature of the sectoral-level capital accumulation process that takes place as a new sector develops. And, second, we will try to understand the extent to which, and the reasons why, the capabilities of entrepreneurial agents come to rely on access to foreign human capital. Hence, our last two sub-questions will be: *what is the nature of the sectoral-level aspects of the process of accumulation of capabilities that takes place as a new infrastructure sector develops?* And: *what influences the extent to which the capabilities of the entrepreneurial agents of a newly developing infrastructure sector come to depend on their ability to tap into the skills of foreigners?*

3.2.3. The Three Cases

The three case studies that we will look at to address these questions are the Chilean utility-scale wind and solar energy infrastructure sectors (Wind and Solar sectors), and the Chilean anaerobic digesters infrastructure sector (AD sector).

The first of these two cases are part of the broader Chilean Electricity Generation sector (EG sector), and their process of emergence was, therefore, part of the transformation process of this last. In both cases, the sector's defining key inputs were the high-tech capital goods which were needed to build wind farms or solar PV systems; their defining key outputs were electricity generation services; and their defining key production processes were the series of tasks which needed to be undertaken in order to develop, build and operate the respective infrastructure facilities (about which more in Chapter 6). And in both cases, the innovations that underpinned the processes of emergence involved using the respective technologies to generate energy for self-consumption or sale to the market. The entrepreneurial agents that first saw these innovations as attractive entrepreneurial opportunities and set to pursue them did so only recently: the first utility-scale wind farms in the country were built in the 2000s, and the first utility-scale solar PV systems were built in the 2010s.

The third of the cases that we'll look at is part of the broader Chilean Waste and Wastewater Treatment sector (WWT sector), and here again its process of emergence was, therefore, part of this last's process of transformation. The defining key inputs of the AD sector were, for the most part, low-tech goods such as cement, steel structures, valves, mixers, plastic membranes, and other such construction materials; its defining outputs were waste treatment services; and its defining key production process were the various tasks needed to develop, build and operate anaerobic digesters (more about these in Chapter 6). Anaerobic digesters, however, generate biogas, and although this by-product was often just burned or simply let to escape to the atmosphere (causing considerable damage to the climate, as biogas, like methane, is a potent greenhouse gas), at times it was put to more productive uses such as thermal or electrical energy generation. Anaerobic digesters with energy generation components are typically more complex than those without. In their case, the list of key inputs must include some medium and sometimes high-tech goods such as internal combustion engines and certain instruments, and the list of key outputs must include energy generation, which to some extent makes them part of the EG sector. The innovation that underpinned the emergence of this new infrastructure sector was the use of anaerobic digesters to treat organic waste – and, as we saw, in some cases to generate energy. The entrepreneurial agents that first saw these innovations as entrepreneurial opportunities and started to pursue them did so from the beginning of the 2000s.

Because the Wind and Solar sectors are fully part of the EG sector (rather than partially part, as with the AD sector), these two cases have much more in common among them than they do with the AD case. A downside of this is that it lessens the variability of the sample and therefore the richness of the comparisons that we will be able to make. But an upside is that, by enabling comparisons among two cases that share many technological and market traits, it will allow us to distinguish better among features of the sectoral development processes that are attributable to these traits from those that are the result of historical circumstances and chance.

3.2.4. Analytical Strategy

The rest of this study consists of three analytical chapters and one discussion and conclusions chapter. Each of the three analytical chapters is a cross-case analysis (Yin, 2013) that focuses on some of the sub-questions spelt out in Section 3.2. These questions, recall, were posed in a general voice. The three chapters that follow, however, will only aim to answer them as if they had been posed in a specific voice, and the task of reflecting on the extent to which these answers can be generalised to other cases will be postponed until Chapter 7.

Thus, in Chapter 4, instead of answering: *how, and when, do the entrepreneurial opportunities that underpin the development of new infrastructure sectors originate?* What we will do in Chapter 4 is to address the question: *how, and when, did the entrepreneurial opportunities that underpinned the development of the Chilean Wind, Solar and AD sectors originate?* To do this, we will first describe more thoroughly the innovations that underpinned the development of each sector, and summarise their career in Chile. Once we've done this, we will go through a number of events that, taking place not long before or just as the new sectoral development process was taking off, made their underpinning innovations be more – or less – attractive entrepreneurial opportunities. As we go through these events, we will weigh their importance, and note the extent to which they correspond with the most widely acknowledged structural change drivers: technical change, changing consumption preferences, fluctuating resource availabilities, and evolving policies and institutions. Once we have done this, we will undertake to compare the relative significance of the events for each of the sectors' underpinning opportunities, and to size up their overall effect on the attractiveness of these opportunities. And then, finally, we will analyse the events in terms of the internal developments/external influences and technology-push/demand-pull distinctions.

In Chapter 5 we will attempt an answer to the question: *what influenced the kinds of economic agent that contributed to the entrepreneurial function, and the nature of their contribution, in the Chilean Wind, Solar and AD sectors?* This chapter will start by describing a number of features of the broader sectors of which the three are part (the EG and the WWT sectors), features which our framework links to some of the things that we aim to find out about the entrepreneurial function: the global context where these broader sectors are enmeshed, the origin and nature of their incumbents, their technological regime, and the nature of the demand they fulfil. After this, we will move on to characterise and analyse the scale and the nature of the contribution that different kinds of entrepreneurial agents made to the function in each case, classifying these agents according to the incumbents – new entrants and the domestic – foreign dichotomies. And on the last part of the chapter, we will discuss the most interesting features of these results, reflecting, as we go along, on the extent to which these features can be explained in terms of the theories that inform our framework.

In Chapter 6, we will address the last two sub-questions: *what was the nature of the sectoral-level aspects of the processes of accumulation of capabilities that took place as the Chilean Wind, Solar and AD sectors developed?* And: *what influenced the extent to which the capabilities of the entrepreneurial agents of these sectors came to depend on their ability to tap into the skills of foreigners?* Each of the two main sections of this chapter will address one of these two questions. In the first of these, we will identify and characterise the main events that contributed to the processes of accumulation of capabilities at the sectoral level. This will enable us to understand their origins and the nature of their contribution to these capabilities in each case. In the second and longest section, we will take a sample of projects from each sector and map the extent to which skilled foreigners were involved in the completion of their key tasks. Then, we will see how a number of hypotheses about what made this vary for different projects and different tasks withstand empirical scrutiny. Finally, we will complement the above with a qualitative analysis of the reasons that led two firms within each sector to rely on foreign skills to the extent they did for their projects.

Chapter 7, as said above, is where we will reflect on the generalizability of these answers. These reflections will be organised around an analysis of cross-case differences and cross-case similarities. In addition, this chapter will address the policy implications of our findings; the limitations of our methods; and the main theoretical contributions of the study.

3.2.5. Data and Methods

The empirical analyses that will follow draw upon a range of different data sources and methods. As these are not the same for all the chapters, and as different parts of these chapters sometimes use different sources and methods, we will go through the specifics as we face the need to do so. It will be useful, however, to go through a brief summary of the main data sources and methods that we will be using. This is done next.

With regards to the data sources, one of the cornerstones of this study, which we use in all three empirical chapters, is a self-compiled database of the three kinds of infrastructure projects that concern us in Chile (self-compiled projects database). The database contains information about 381 wind, solar and AD projects at various stages of development (some of them already built/executed, and some shelved or still under development) that I compiled. In the case of Wind and Solar, the initial data about these projects came from the website of the government's environmental evaluation service. This body, called *SEIA*[17], must approve all utility-scale (over 3MW) wind and solar projects before these can be built, and their list is therefore the total universe of projects that have crossed the development-stage milestone of sending a request for approval to them. In the case of AD projects, some of the initial data also came from this organisation, but not all of it. The reason for this is that only the largest AD projects are required to go through the SEIA, and limiting the inquiry to these projects only would have resulted in too small a sample. The list of AD projects was therefore augmented with data coming from various other sources, including consultancy reports (Chamy, 2007; GAMMA INGENIEROS, 2011), websites, and interviews. Although, in this case, the data does not come from a single and systematic source, the list probably includes most projects which have gone beyond pre-feasibility studies.

For all of the projects on the sample, I compiled data about a) their history and status (start of development date, current status, and start of operation date if the project had already been built); b) their project developer (name of the firm/organization that developed the project and kind of firm this was based on the incumbents/new entrants and local/foreign distinctions); c) if the project had been built, their project sponsors (same information as project developer); d) the project's size (in MW for Wind and Solar project, and in cubic meters of biogas generated per years for AD projects; and, for a limited number of projects for which this data was available, on monetary value); and e) if the project had been built, on the kind of relation among the project developer and sponsor (whether the

---

[17] *Servicio de Evaluación de Impacto Ambiental*

developer was an independent developer, a consultant or a sponsor). For most projects, I had to assemble this data from various sources. Besides the SEIA and consultancy reports, the most prominent among these sources were: a) the environmental impact reports that projects submitted to the SEIA; b) the Bloomberg New Energy Finance database, which had basic information about most Wind and Solar projects, and which was freely (but limitedly) accessible through a Google search; c) the BNAmericas database, which contains similar information for some projects and which can also be accessed in a limited way through a Google search; d) the websites of the project developers or the project sponsors, which often contained information about the projects; e) the CDM Project Design Documents of those projects which were CDM registered, all available through the UNFCC project search facility[18]; and f) fieldwork interviews. In some cases, the information coming from these sources was used directly, and in some other cases, it was used as a basis to make educated guesses about variables of interest. This was, in particular, the case with data about the size of AD projects, which came in various different formats which I had to normalize to m3 of biogas/year by making reasoned guesses and extrapolations (in some cases the size of the project was listed in monetary terms, in other cases in terms of biogas generation per time period, in some others in terms of the volume capacity of the anaerobic digester, etc.). And this was also the case with data about the kind of firm that project developers and project sponsors were, and about how they related to each other in specific projects, which was rarely available directly, but which could be reasonably guessed based on project descriptions, the timing of key events, the websites of firms, and news articles from various sources.

A second key source of data comes from two questionnaires that I applied to several executives and engineers that were involved in one or more of the projects of their respective sectors. One of these questionnaires (project questionnaire) asked for detailed information about specific projects, and the other for more general information about the tasks that need to be undertaken to complete these projects (tasks questionnaire). The answers to both of these are used extensively in the second and largest section of Chapter 6. In this chapter, I also describe in detail what it is that I asked in these.

A third major information source of this study are extensive fieldwork notes that I took as I interview people from each of the three sectors. Most of these people were engineers and managers of firms engaged in the development or the sponsorship of projects. But some also were from the government, from industrial associations, and from

[18] cdm.unfccc.int/Projects/projsearch.html

other kinds of organisations. These fieldwork interviews were not, however, undertaken with a view of deriving systematic data from them (e.g. by transcribing and coding responses), and moreover not all interviewees were asked the same questions. Thus, although, they are used to inform all of the chapters that come, what these interviews provided was anecdotal data: the systematic part of our evidence base comes from the projects database and the questionnaire responses. The anonymized full list of people that I interviewed, including the kind of organisation that each of these worked at, and what the interview consisted on, is available in Appendix A.

Other sources of information include several tens of third-party electronic documents collected from various sources, including some with tabulated data on electricity prices and other such quantitative data.

With regards to the methods, we will largely rely on 'simple' weighing of the evidence that we use to support the different arguments that we make, except for Chapter 6 where we will undertake some statistical analysis of interviewees' responses. In most cases, the evidence base will not enable us to make categorical judgements about the matters that we will try to settle, but this does not need to stop us from making any judgements at all. In order to move safely in the broad grey zone that exists between categorical judgements and no judgements at all – which is the only one we can inhabit in an exploratory study like this –, we will aim to transparently present the evidence base from which we draw any conclusions, and to adjust the language that we use to spell out these conclusions so that it matches the strength of this evidence base. Also, by the end of each analytical chapter, we will present a table to summarise the main methods, data, and operational assumptions or definitions that we used.

Chapter 4
The Entrepreneurial Opportunities

How, and when, did the entrepreneurial opportunities that underpinned the development of the Chilean Wind, Solar and AD sectors originate?

The economist Arnold Harberger once used yeast and mushrooms to explain why Total Factor Productivity (TFP) did not increase at even rates for all sectors. The analogy, he wrote, 'comes from the fact that yeast causes bread to expand very evenly, like a balloon being filled with air, while mushrooms have the habit of popping up, almost overnight, in a fashion that is not easy to predict' (Harberger, 1998). Much the same happens with entrepreneurial opportunities. Like mushrooms and TFP improvements, these too pop up in a fashion that is not easy to predict, even if this doesn't happen overnight.

But although their emergence is hard to predict, it is fully possible to investigate the origins of an entrepreneurial opportunity once it has been identified as such. The aim of this chapter is to do just this. In the first section, we will identify the innovations that underpinned the emergence of the Chilean Wind, Solar and AD infrastructure sectors; determine the moment in time when the development process of these sectors took off; and trace the career of these innovations until 2016. In the second section, we will identify and size up the significance of a number of events that, taking place not long before each sector took off, were crucial in turning these innovations into more – and in a few cases less – attractive entrepreneurial opportunities. In most cases, as we will see, these events correspond with one or more of the most widely acknowledged structural change drivers: technical change, changes in consumption preferences, fluctuating resource availabilities, and evolving policies and institutions; however, in a few cases they don't. In the next section, we will make an overall assessment of the effect of these events on the opportunities, so as to find out whether these last had already been attractive ones long before each sector took off, or whether they became attractive not long before this happened. In the fourth section, we will characterise these events in terms of the internal developments/external influences and supply-push/demand-pull contrasts, and reflect on some of the interesting features of what the contrasts show. And in the last section, we will wrap up things.

4.1. The Underpinning Innovations and Their Career in Chile by 2016

The innovations that underpinned the development of the three infrastructure sectors under study were wind farms, solar PV systems and anaerobic digesters. What follows is a brief account of their career in Chile from the moment the first of these were built until 2016. The objective is to present the three case studies as short histories that we can then build upon and compare. In doing this, however, we must confront the fact that new sectors seldom emerge from nothing. As one traces their history, one will always find antecedents that may largely pre-date the time when they become distinguishable: conceptual designs that were never pursued, pilot projects that were never scaled, pioneer firms that failed, or even sizable early investments that were not soon followed by others. This organic nature of new sector development processes makes their dating somewhat arbitrary. Nevertheless, we will need to establish a criterion to date these processes, as, without this, our comparative analyses would not be feasible. Thus, in all of what follows, we will consider that a sector's emergence process 'takes-off' in the year from which at least three different non-pilot facilities sponsored by at least three different economic agents have become operational. This criterion is ad-hoc and may not be adequate to date all sorts of new sector emergence processes. However, the criterion proved a sensible way to date the three being studied, providing a shared, objective, and useful temporal milestone.

4.1.1. Wind Farms

In the first half of the 2000s, wind farms in Chile were a rarity: only one such facility had been connected to any of Chile's four electricity grids, and this was a very small one which was not connected to either of the two major grids in the north and centre-south of the country, but rather to one of the two small grids in the far south. Although this wind farm – largely because it was built in a location with excellent wind conditions[19] - had been commercially successful[20], no others had followed it. The few other wind farms that could be found in the country were non-utility-scale off-grid facilities, most built under the aegis of a government program (the *Rural Electrification Program, or REP*[21]) aiming to provide electricity access to isolated rural areas. However, beginning in the middle of the decade, things started to change. From then on, a variety of different firms began to scout the land for good wind conditions, and to develop projects where they found them. A number of others quickly followed, and investments started to materialise from 2007 (Figure 4.1).

---

19 Communication from PPHR82. Also, since it became operational the Alto Baguales has had an unusually large plant factor (of 0.39 according to Moreno et al., 2006).

20 Communication from PPTX31.

21 We will document the contribution of this program to Wind and Solar capabilities in chapter 6.

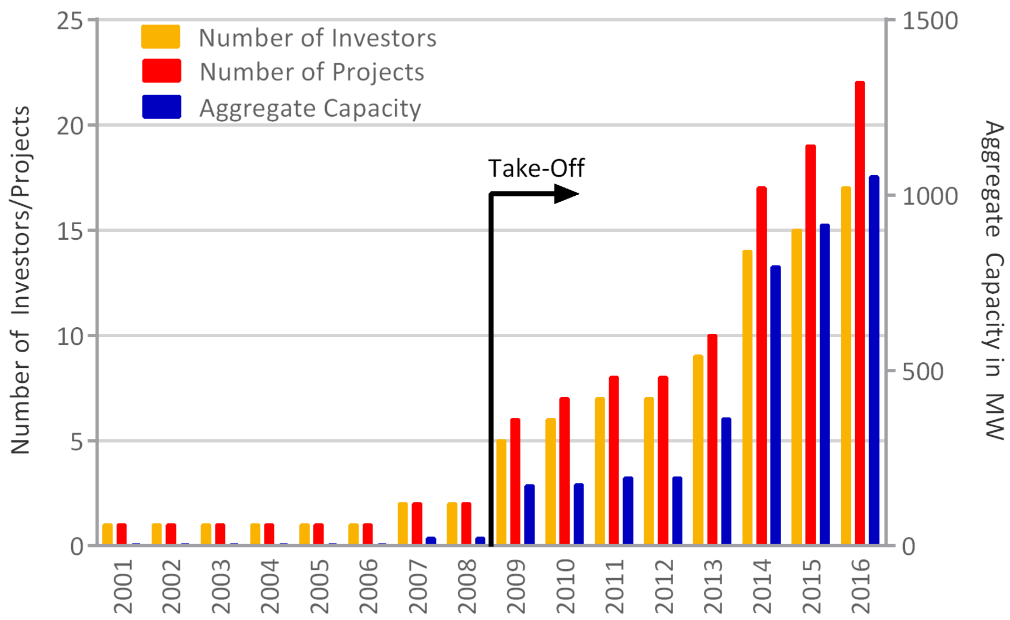

Figure 4.1: The development of the Wind sector. *The take-off arrow indicates the first year when at least three different investors had sponsored at least three non-pilot projects. Source: own elaboration based on self-compiled projects database.*

By the definition of take-off employed in this study, the Wind sector took off in the year 2009**.** By the end of this year, five different firms had sponsored six grid-connected facilities, most of these smaller than the ones that would come, but all of them sizable non-pilot ones. These facilities were part of what one interviewee[22] regarded to be the first of two different generations of wind farms in the country: the first composed of the seven that became operational between 2007 and 2011; and the second of the fourteen that, at the time of writing this, were under construction or had become operational after 2012 – this last a year in which no new investments materialized.

This split of the wind story in two time periods had a solid basis. There were real and substantial differences among one and the other generation. The first difference had to do with the average size of the projects, which – unsurprisingly – was smaller for the first generation: about 23MW, compared 60MW for the second one[23]. And another difference, which was perhaps more important, had to do with their quality: while the six first-generation wind projects for which I was able to get operation data had a plant factor[24] of

[22] PPZX82.
[23] Based on self-compiled projects database. This is without counting later expansions.
[24] The plant factor of a power plant is the actual amount of electricity it generates in any given period relative to the maximum amount of electricity it could theoretically generate under optimal conditions. In the case of wind farms, optimal conditions would mean 24 hours constant wind of the

0.19, the five second-generation ones for which I got this data had a plant factor of 0.29. As these low plant factors show – and as more than one interviewee explained[25] – first-generation wind farms were often technically defective, not properly designed or built on sites with inappropriate wind conditions.

One more significant difference among the two generations of wind farms was the kinds of firms that sponsored them. Few first generation sponsors – as we will document more thoroughly in Chapter 5 – were new domestic firms or newly established subsidiaries of MNEs: most were pre-established firms[26]. Some of these were the incumbent utilities of the EG sector, and some diversifiers from the industrial or mining sectors for whom this was their first electricity generation investment. Second generation sponsors, on the other hand, were predominantly new entrants, and more specifically newly established subsidiaries of MNE energy utilities from Europe, the US, and Latin America. This group was dominated by the Italian *Enel Green Power* (EGP), whom with its five wind farms totalling about 450MW of installed capacity was by 2016 the owner of about 40% of all operational or under construction wind generation capacity[27].

The development of the wind sector drew on the support of a number of pre-established firms that developed capabilities to offer ancillary services in areas such as construction management, legal advice, or environmental management[28]. These included *Burger Gruas*, whom brought the first high altitude cranes – needed to assemble aerogenerators – to the country; *Agencia de Aduanas Patricio Sesnich*, whom specialised in managing the logistics of the import of aerogenerators; and others like them. However, the development of the sector also saw the establishment of several new ancillary services firms. These included *Garrad Hassan*, whom offered due diligence services to financial institutions and sponsors evaluating whether to finance or acquire a project; *VESTAS*, whom opened a subsidiary in the country to facilitate the acquisition and the provision of repair and maintenance services for their aerogenerators; and others alike. The new arrivals tended to fill the gaps that previously established firms would not. These gaps were mostly in the wind-specific engineering requirements of projects, such as the conduit of wind

right speed to keep the aerogenerators working at full capacity, which explains why their plant factors are often low compared to those of non-intermittent generation technologies such as thermoelectricity. I calculated the plant factors of wind farms based on data about their yearly operation available on www.cdecsic.cl/informes-y-documentos/fichas/operacion-real/

[25] PPHQ93, PPZX82, PPYH72.

[26] 5 of the 6 of them were such kinds of firms, and the other was a joint venture in which one of the parties was also a pre-established firm.

[27] Based on the self-compiled projects database.

[28] Based on projects questionnaire.

prospecting campaigns and the design of the plants. Some of these ancillary services firms were also project developers in their own respect.

If the trends of the monthly *Comision Nacional de Energia (CNE)* reports[29] continue, the more than 1GW of wind generation capacity that ought to be operational by the end of 2016 should by then be generating some 3% to 5% of the country's electricity[30]. For reference, the equivalent figure for the world in 2013 was 3%, and was projected to be anywhere from 6% to 15% by 2040 (IEA, 2015). 3% to 5% may seem little, and 1GW of wind capacity is a long way from the 40GW or so of technical potential estimated in the most authoritative study (Santana, 2014), but considering a cost of 1.340 to 2.330 USD per installed kW (the Figures are taken from IRENA, 2015) and doing the numbers, one gets that anywhere from 1.3 to 2.3 billion USD will have been invested in the Wind sector in the ten years from 2007 to 2016. This is no trivial figure for a country as small as Chile, where the 2015 estimated GDP was of 424.3 billion USD (2015 USD, ppp.)[31]. Moreover, the emergence of the Wind sector in the country is still in its infancy – as it is in most of the world. Many more wind farms are set to be built in the future.

4.1.2. Solar PV Systems

In the first half of the 2000s – much like wind farms – solar PV systems were a rarity in Chile. Unlike wind farms, however, these remained a rarity throughout the 2000s. Here, again, most of the solar PV systems that one could find in the country in these years were the small-scale off-grid systems sponsored by the government's *Rural Electrification Program*. This was despite the fact that it had long been known that the northern part of the country, dominated by the *Atacama Desert*, possessed some of the best solar radiation conditions in the world (Löf et al., 1966). So, as the first wind farms were being built, solar PV systems lagged behind. But then, all of a sudden, five different small pilot facilities became operational in 2012 and 2013. This was the dawn of a sector which was destined to grow at a rate that, compared to that of other electricity generation technologies, was strikingly fast (Figure 4.2).

[29] Available at www.cne.cl/en/nuestros-servicios/reportes/informacion-y-estadisticas/

[30] These reports shows that on the first months of 2016 wind was generating 5% of the electricity of the centre-south grid, which represents about 75% of the electricity demand of the whole country. These Figures are the source of this rough estimate.

[31] CIA World Factbook, www.cia.gov/library/publications/the-world-factbook/geos/ci.html

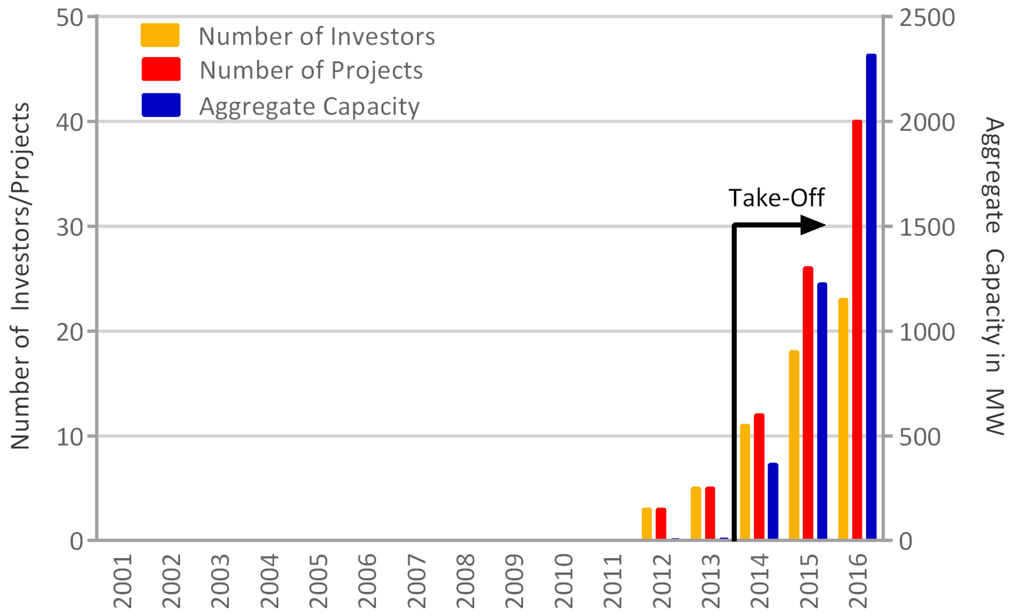

Figure 4.2: The development of the Solar sector. *The take-off arrow indicates the first year when at least three different investors had sponsored at least three non-pilot projects. Source: own elaboration based on self-compiled projects database.*

The emergence process of the Solar sector took off in the year 2014. This was the year in which the first non-pilot facilities were built, and new sponsors were by then pouring in. One year after the take-off, there were already more than fifteen different ones – a milestone that took Wind six years to reach. The average size of the facilities that these sponsors were investing on quickly rose from the 1.5MW of the pilot years to 34MW in 2014 and then 83MW in 2015, to then remain close to this number in the next year.

The emergence of the Solar sector was from the outset driven by FDI. From the beginning, the majority of the new sponsors – thirteen out of the twenty-three that had invested in projects by 2016 – were newly established subsidiaries of MNEs, some of these not just utilities but also solar PV system component manufacturers. Their number in relation to the other kinds of sponsors does not, however, provide a balanced view of their role, for though they represented 57% of the total number of sponsors, this 57% were the owners of about 72% of all the facilities and 80% of all the installed capacity. In other words, the new subsidiaries were not just more numerous than other kinds of sponsors, but also they on average built more and larger facilities than them.

A handful of these Solar sector sponsors were also Wind sector sponsors, most notably *EGP*. But here this firm had not the first but rather the second largest market share, being surpassed by the *SunEdison* from the USA. The market concentration in Solar, however, was nowhere near the level it had reached in Wind by 2016, for if by then the Italian *EGP* owned about 40% of the Wind capacity, by the same date *SunEdison* owned only about 20% of the Solar capacity.

The overlap of the Wind and Solar sectors was, however, much deeper than the mere existence of a few common sponsors. A number of wind project developers, including some of the leading ones, were also solar project developers, and many of the firms providing ancillary services to the Wind sector also provided these to the Solar sector. This was the case for both the newly established, new subsidiary dominated ancillary services firms, and also for the pre-existent ones, which were more often of a domestic origin.

By 2016, solar generation was already surpassing wind generation in some months: whereas, in February 2016, 2.8% of the energy of the two major grids had come from solar PV systems, only 2.7% had come from wind farms (CIFES, 2016). Considering that Solar took off five years after Wind, and that it caught up with it only two years later, this was quite a feat. Assuming a cost of some 1.690 to 4.250 USD per installed kWh (IRENA, 2015) and doing the numbers, one gets that anywhere from 3.9 to 9.8 billion USD had been invested in the Solar sector by the end of 2016, i.e. perhaps three to four times as much as in Wind. Everything – not least the much higher technical potential of Solar, orders of magnitude higher than that of Wind (Santana, 2014) – suggests that this trend will continue. So much has the Solar sector grown in the north of Chile, and so rapidly, that the main bottleneck for further expansion is the transmission system, which doesn't currently have the capacity to transport all of this energy to the main energy consumption centre: the *Metropolitan Region of Santiago*. Such bottlenecks, however, are likely to be eliminated in the near future, and soon the new bottlenecks will become the intermittency of solar generation and the relatively small electricity needs of the country. Some, however, are tackling these issues and looking beyond, and dream about turning Chile into an exporter of energy to other South American countries[32].

4.1.3. Anaerobic Digesters

In terms of their size and their purpose, anaerobic digesters are much more varied than their Wind and Solar counterparts. In Chile, these facilities were pioneered in the first half of the 2000s by the lead swine producer of the country, an agro-industrial conglomerate

[32] Most notable among these is the Chilean startup Valhalla (valhalla.cl), an innovative initiative that is developing large solar PV + pumped-hydro storage systems which can solve these intermittency issues and that seem to be well on track to the realization of this vision.

called *Agrosuper* that started to build them as a component of their industrial complexes' waste treatment systems. Waste treatment, as we've seen, is often the main purpose of anaerobic digesters. In this, Chile was no different, although some sponsors eventually invested in facilities with thermal and later electrical energy generation components. Although the performance of these systems in the decomposition of organic matter was highly dependent on – among many other context variables – the type of effluent to be treated, there were various niches where they could potentially perform better than alternatives (Muga and Mihelcic, 2008). Alternatives, however, were sometimes cheaper, and often close to free, as the 'waste treatment system' of many a company consists in dumping untreated waste in whatever nearby location they can. With this balance of pros and cons, for a number of years after their introduction by *Agrosuper,* no one seemed to be interested in sponsoring more of these digesters. Eventually, however, the followers arrived (Figure 4.3).

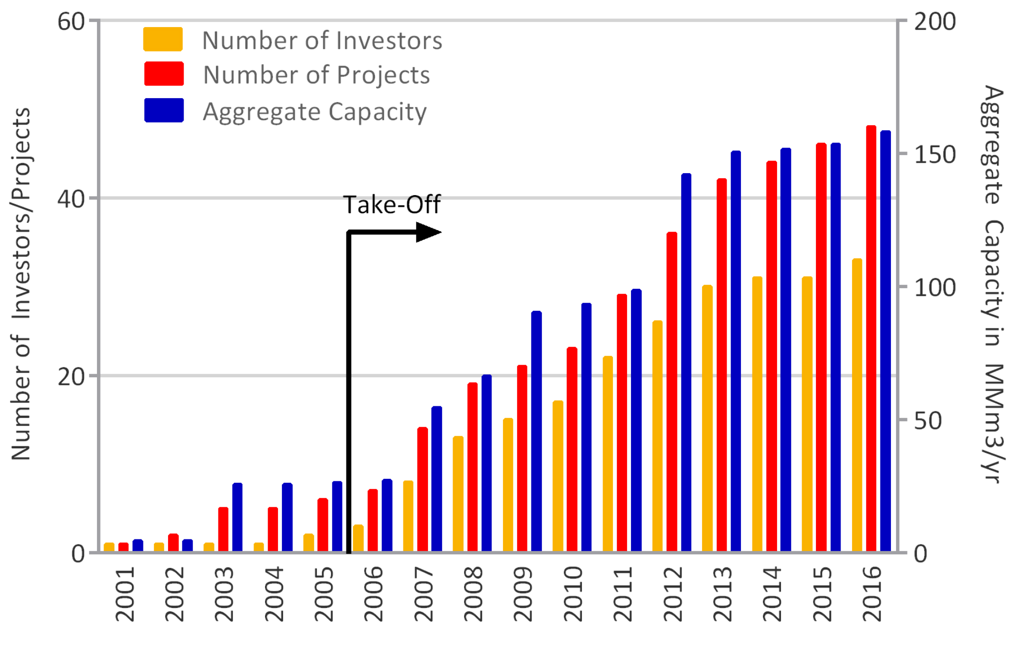

Figure 4.3: The development of the AD sector. *The take-off arrow indicates the first year when at least three different investors had sponsored at least three non-pilot projects. Source: own elaboration based on self-compiled projects database.*

The emergence process of the AD sector took off in the year 2006. The single anaerobic digester that entered into operation in that year marked the milestone of the three different sponsors, though still by then *Agrosuper* owned five of the seven existent facilities, and these were up to ten times as big as those of the first two followers. These large differences in size were not, however, the result of the cautious building of pilot plants that would be scaled if they performed well, but rather the reflection of the different waste treatment needs of sponsors that went from the small family farm to the large agro-industrial complex. Thus, the differences persisted, and the smallest of the more than 40 facilities that more than 30 sponsors had invested on by 2016 were three orders of magnitude smaller than the largest.

A number of these digesters, and in particular some of those built in the five years after the take-off, did not perform well. Some facilities were therefore abandoned, and at least one interviewee[33] thought that had caused significant damage to the technology's reputation, discouraging potential new sponsors. A case in point is that of the *HBS Los Angeles* project, a large one and an important milestone for the sector, this because when it became operational in 2010, it was the very first facility in the country to generate electricity for injection to the grid. Most previous facilities had just flared – i.e. not used – the biogas they generated, though a few had used it for thermal energy generation or off-grid cogeneration. Though *HBS Los Angeles* was completed five years after the sector's take off, the fact that it was a grid-connected electricity generation facility meant it was perhaps as innovative as the first waste-treatment-focused AD facilities had been, marking the start of a new phase for this sector. The project, however, was a failure, and though it was not abandoned, it was riddled with technical problems, and it generated far less electricity than it had been expected[34]. Well-functioning anaerobic digestion facilities were hard to build and even more difficult to run, particularly so when they included electricity generation components. These facilities required far more adaptation to the local conditions than their Wind and Solar counterparts.

Some firms, however, persisted in the use of this technology, and a number of them eventually succeeded. Success seemed to require not just technical knowledge and ingenuity, but also the finding of a good niche market. Thus, the most successful developers of anaerobic digesters were those that were able to detect a promising niche and specialise in the design of systems well adapted to its needs. This was the case of *Schwager Energy*, whom specialised in multi-purpose waste-treatment-and-energy-generation facilities for industrial milk processing plants. And also of *Biotecsur*, whom specialised in facilities for

[33] PPUX25.
[34] Based on interviews with PPOT34 and PPUX25.

small-to-medium sized livestock farms. But these successes did not come easy, and their coming took years of often unrewarded efforts.

Unlike the Wind and Solar sectors, the development of the AD sector did not seem to have caused the development of an ancillary services sector. In interviews, few organisations other than the developers and the sponsors were named as participants in the projects: the ancillary services firms of the sector were the developers themselves, working side by side with the sponsors to design and build the facilities. Likely, this was because the market for these was small compared to the market for wind farms and solar PV systems, and also because these were usually relatively small facilities. Also in contrast to the Wind and Solar sectors, few of these sponsors and developers were the newly established subsidiaries of MNEs: most were domestic firms.

The AD sector that developed in these years was far smaller than its Wind and Solar counterparts. Data from the few projects for which money-related information is available suggests that at most a couple of hundredth million dollars have been invested in the building of these facilities since the sector took off[35], a figure much smaller than the several billion dollars involved in the two other cases, and one which has taken longer to accumulate. This, however, is not surprising, as the potential for investment in AD facilities of the sort being studied is limited by the waste treatment needs of a handful of domestic economic sectors. In this respect, one authoritative study from 2007 concluded that the potential for electricity generation from biogas in the country was of 400MW, and this included not just the electricity that could be generated from biogas captured in anaerobic digesters, but also that which could be captured from the landfills which naturally generate it (Chamy, 2007). Though this estimate may be conservative, it is still three orders of magnitude smaller than the equivalent figure for Wind, and several more orders of magnitude smaller than that for Solar. There are, however, unexplored niches in which anaerobic digesters could find a place. Little by little the sector has matured, and there are now three or four firms that have managed to establish themselves as successful AD developers and are thus well placed to tackle these niches. It remains to be seen whether they succeed.

[35] I made this order-of-magnitude calculation by extrapolating data from the few projects for which I was able to get investment costs data.

4.2. The Evolution of the Context around the Take Off Year

As we have seen, once a sector starts to develop, exogenous forces and its own development process will normally affect the entrepreneurial opportunities that underpin it. In other words, the attractiveness of a sector's entrepreneurial opportunities does not get fixed in time once a sector takes off, but it is rather continually changing. In this, the Chilean Wind, Solar and AD sectors were no different: once they took off, changes in prices, the entry of competitors, the passing of new regulations, and other such events regularly changed the landscape faced by entrepreneurial agents.

This landscape, however, may also change *before* a sector takes off. As we've seen, finding out whether it did so, and in which direction, is of significant interest. This is because if the innovations that underpin a sector can be shown to have been utterly unattractive entrepreneurial opportunities in the years before the sector took off, then one may justifiably conclude that their becoming attractive must have been one of the leading proximate causes of its development. On the other hand, if an analysis of events through these pre-take off years yields no evidence suggesting that the opportunities in question were not as attractive in the past as they were when the sector took off, then one may justifiably conclude that the failure of the sector to develop earlier was not due to a lack of attractive opportunities, but rather due to other reasons, such as – although not the only possibility (Hausmann et al., 2008) – lack of entrepreneurship (Hausmann and Rodrik, 2003) – or, in our terms, a weak entrepreneurial function.

Driven by these considerations, this section, and the rest of the chapter, is an attempt to characterise and gauge the magnitude and the direction of changes in the attractiveness of the entrepreneurial opportunities we're concerned with in the years before each sector took off. But before we engage in this undertaking, we need to define what we mean by *before*, for looking at events that occurred one-hundredth years before a sector takes off is very different from looking at those that took place ten or one year before.

Perhaps inevitably, the selection of this timeframe will be to some extent discretionary, and based on what we want to achieve. Very long time periods, in the several tens or hundredths of years, are not really proportionate to the kind of sector that we are focusing on and to the kind of inquiry that we aim to undertake: while trying to understand how a broadly defined sector such as 'modern manufacturing' emerged may well justify a deep look at the past, trying to understand how more narrowly defined sectors such as the ones we are studying developed seems best served by a shorter timeframe. But too short a timeframe can also be inadequate, for placing too much importance in what happened one or two years before a sector took off will likely result in a myopic perspective. Taking these considerations into account, we would seek to limit our quest for events with a significant impact on the underpinning opportunities to the ten years before each sector took off.

Practical considerations, however, make it necessary to extend this period to the two years after the take-off year, so that the timeframe we cover is the twelve years that go from ten years before the take-off year to two years after – a timeframe that we will refer to as 'the germination period' of each sector. The practical considerations relate to the fact that, in some cases, some very relevant events took place in these two post-take-off years – particularly in the case of the Solar sector – and not going through them would be to miss an important part of the story. Not much harm is done by this extension, however, as the 'feedback effects' that would, in time, lead to significant *endogenous* changes in the attractiveness of the opportunities had not yet kicked off two years after any of the sectors' take-off years[36].

As we've seen, entrepreneurial opportunities are the result of causal chains that are not just indefinitely long but also indefinitely broad and complex. Because of this, the aim of what follows is not the impossible one of identifying every single event that may have affected the attractiveness of the three entrepreneurial opportunities in the germination periods, but rather the more manageable one of identifying, characterising, and sizing up only the most important events. To find out which these were, the method I followed was to ask interviewees to point and explain the events that they thought contributed the most to the process of emergence of the respective sectors, and the ones they thought were most detrimental to this process. Their answers led to several dozens of pages of fieldwork notes, which I then used as the starting point for a deeper inquiry into the events that were emphasised the most. The conduit of this investigation started by discarding the events that did not fall within the germination periods of the three sectors. I also discarded the events that were part of the processes of accumulation of domestic capabilities that were directly associated with the emergence of each sector, for, as we have seen, we are not considering these as part of what makes entrepreneurial opportunities more attractive, but rather as part of the process by which economic agents learn to pursue these opportunities – which means ought to be analyzed in Chapter 6 rather than here. Whenever this was possible, I looked for quantitative data to enable a more objective evaluation of the effect of each event on the respective opportunities. This, however, was not always feasible, and in some cases,

[36] Endogenous in the sense that they were caused by the process of development of the sector itself, such as opportunities becoming less attractive because of fierce competition or electricity transmission infrastructure bottlenecks.

all that is available to judge the strength of the effect of an event or group of events is qualitative data.

One feature of the account that follows is that it consists, for the most part, of events that had a positive rather than negative effect on the opportunities. This, however, is simply a reflection of the answers of interviewees. In all cases, most of the events that these listed as having negatively affected the allure of the respective opportunities took place several years after the emergence processes had taken off, and were, for the most part, an endogenous effect of the development of the sectors: increased competition, bottlenecks in the electricity transmission system, the bad reputation brought to the sector by failed projects, etc. These events thus fall outside of the germination periods, and also outside of the more general scope of this chapter, which – as we have seen – is not concerned with the effect of these post-take-off feedback effects on the allure of the opportunities.

Although new entrepreneurial opportunities tend to pop up unexpectedly and for a variety of reasons, their appearance, as we have seen, is commonly attributed to a few 'usual suspects': technical change, changing consumption preferences, fluctuating resource availabilities, and evolving policies and institutions. Because they overlap, are not independent, and don't cover all the possibilities, these common and widely known structural change drivers are not a classificatory scheme that we can fruitfully use to organise what comes. But many of the events below do fall within the span of these archetypal drivers, and in order to better engage with their associated literature, we will discuss, as we review them, the extent to which they correspond to some of these 'usual suspects'.

4.2.1. The Price of Fossil Fuels and the Argentinian Gas Crisis

The most important way in which fluctuating resource availabilities affected the attractiveness of the entrepreneurial opportunities that underpinned the Wind and Solar sectors – and, to a lesser extent, the ones that underpinned those of the AD sector[37] – through their germination periods was through their effect on the competitiveness of fossil-fuels-powered thermoelectricity. As Figure 4.4 shows, a large share of the electricity that was produced in Chile from 1999 to 2010[38] was produced by either coal, oil, or gas powered generation facilities. Alongside hydroelectricity, these conventional energy generation

[37] As we've seen, the primary purpose of most AD facilities was waste treatment, not electricity generation. The competitiveness of thermoelectricity was therefore less relevant to these.
[38] Disaggregated data for the period after 2010 was unfortunately unavailable, but by 2016 the overall trend has not undergone any radical changes.

technologies were the main competition of wind farms, solar PV systems, and the handful anaerobic digesters that had electricity generation components. Because of this, their fate was firmly tied to the fate of the Chilean Wind and Solar sectors, and to some extent also to that of the AD sector.

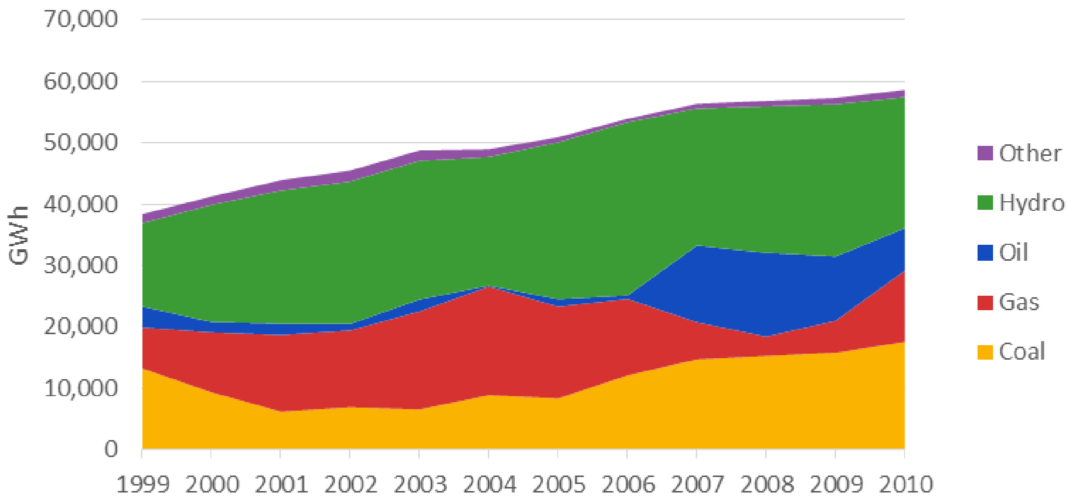

Figure 4.4: Electricity generation by technology in Chile's energy system. *Source: own elaboration based on data available at energiaabierta.cl/balance-energetico/*

The competitiveness of thermoelectricity is largely determined by the prices of fossil fuels, and the trajectory of these prices is thus the relevant variable. Figure 4.5 shows indicators of the evolution of these prices through the period of interest, both in the World and, from 2005 onward, in Chile (I was unfortunately not able to find price series data for Chile before 2005). Except for that of gas, the trajectory of the Chilean prices tended to follow the trajectory of World prices, which is a consequence of the fact that the country imports the large majority of its fossil fuels (Sabbatella, 2015). The divergence of the Chilean price of gas with respect to the World price, on the other hand, is largely explained by a series of events that took place from 2004 onward and which became collectively known as the Argentinian Gas Crisis.

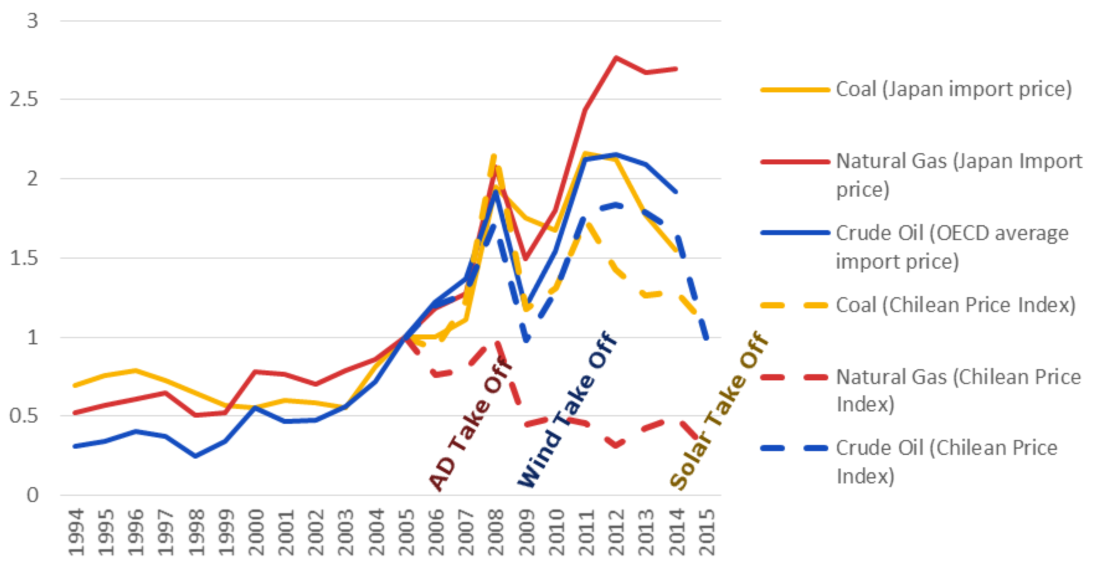

***Figure 4.5*: The trajectory of fossil fuel prices in Chile and the World.** 2005 = 1. *Source: own elaboration based on tabulated data available in (British Petroleum, 2015) (World prices) and energiaabierta.cne.cl (Chilean prices).*

The Argentinian Gas Crisis took place when this last country decided, from 2004 onward, and for internal political reasons (Huneeus, 2007), to drastically reduce their gas exports to Chile (Figure 4.6). This event dramatically reduced the country's ability to import this key fossil fuel, this because, at the time, Argentina was the only feasible import partner: for geopolitical reasons, gas imports from Bolivia and Peru – the two other bordering countries – were unfeasible, and in these years Chile did not yet possess the infrastructure needed to import liquefied gas. As a consequence, gas-powered electricity generation declined, reaching a nadir in 2008 (Figure 4.4). Although, as said above, the relevant price series are not available to us to corroborate it, the above makes it very likely that the Chilean price of gas had reached a historical high in the years from 2004 to 2008, and that its posterior – and, at first sight, puzzling – decline against the World trend, was a return to normality brought about by adaptations from both the demand side (less investment in gas-powered generation capacity) and the supply side (the entry in operation, from 2010, of infrastructure able to gasify liquefied natural gas, which could be imported from – in principle – anywhere in the world). It is also likely that, before 2005, Chilean gas prices had tended to move much more in tandem with World prices – like coal and oil prices were doing after this year.

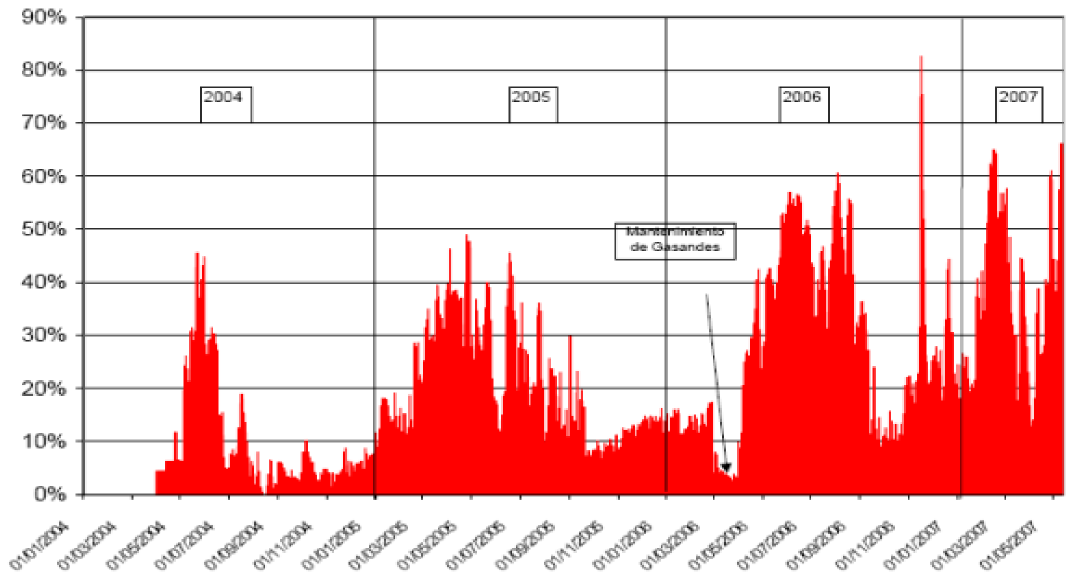

__Figure 4.6: Gas restriction from Argentina.__ The figure shows the percentage of the restriction with respect to normal requirements. Source: hrudnick.sitios.ing.uc.cl/alumno07/gas/objetos/Abastecimiento%20de%20Gas%20Natural.pdf

As the germination periods of the Wind, Solar and AD sectors don't coincide, the way in which the trajectory of these prices affected the attractiveness of the respective entrepreneurial opportunities was not the same for all sectors. In the case of AD, the trend of fossil fuel prices through the AD germination period (1996 to 2008) was largely upward. This negatively affected the competitiveness of thermoelectricity, and thus positively affected the potential competitiveness of AD-based generation. Electricity generating AD facilities, however, were not built until well after this sector's germination period: as we'll see below, the first electricity generating AD facilities were built in 2010.

In the case of Wind, prices from 1999 to 2011 were also going up until the Argentinian Gas Crisis and the severe shocks of 2009 – probably related to the 2008 international recession – started to disrupt them. Although the disruptions sometimes led to price falls, these falls were either temporary (2009, coal and oil) or the aftermath of a contingent peak (2009, gas). In these years, the commodities boom that the world was experiencing was still the dominant trend, and investors could not have known that it was about to be reversed (Gruss, 2014). Therefore, as with AD, the trajectory of the price of fossil fuels during the Wind germination period was, overall, a factor that made this technology more competitive relative to thermoelectric generation.

In the case of Solar, prices in the germination period (2004 to 2016) were even more unstable than in Wind, for, in this case, the end of this period coincided with the reversal of the commodities boom which took place from about 2011 onward (Gruss, 2014). Thus, in this case, it makes little sense to talk of an 'overall effect' of these prices in the attractiveness of the opportunities, for while in the first two-thirds of this period (2004 to 2011) things were improving (fossil fuel prices were broadly going up), in the last third they were clearly deteriorating (fossil fuel generation was becoming more competitive). However, it is notable that this sector took off at a period when the fall of fossil fuel prices was already large enough to nullify most of the loss of competitiveness that thermoelectricity had suffered from 2004 to 2011 (Figure 4.5), and when there was, moreover, no reason to believe that the fall would suddenly stop. In other words, the Solar sector took off when fossil fuel prices were making thermoelectricity at least as competitive as it had been at the beginning of this sector's germination period – although, crucially, many solar projects were developed, and the first few were built, when thermoelectricity's competitiveness was still falling[39].

4.2.2. The Price of Electricity

The competitiveness of non-conventional renewable energy (NCRE) technologies (such as Wind, Solar and AD electricity generation facilities) is more directly affected by the price of electricity than by the price of fossil fuels. The price of fossil fuels, in fact, impacts the competitiveness of NCRE technologies through its effect on the price of electricity. And, although the price of electricity in Chile depends on the price of fossil fuels, it also depends on a number of other factors. Figure 4.7 shows the evolution of the most important electricity prices in Chile from 1991 to 2015: the node prices that guided payments for electricity sold through Power Purchase Agreement (PPA) contracts, and the spot prices that guided payments in the day-to-day spot market, this for the two major electricity grids. One can see there how radically these prices increased from about 2000 to 2008 – by as much as 400% – right through much of the germination periods of all three sectors, to then slowly decline.

[39] Here it is useful to remember that the take-off year was defined in terms of operational facilities, but – at least in the Wind and Solar sectors – more than a few facilities were developed before any became operational, as we'll see in the next chapter.

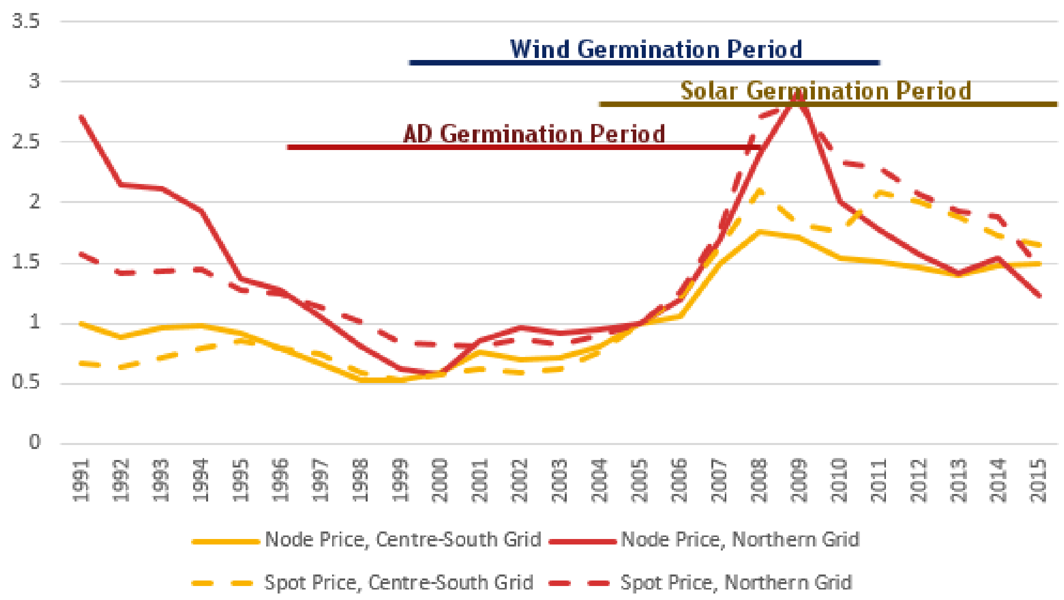

Figure 4.7: The trajectory of electricity prices in Chile. *2005 = 1. Source: own elaboration based on data available at www.cne.cl/en/estadisticas/electricidad/*

There were two main causes for these price increases. The first was the already mentioned Argentinian Gas Crisis, one of whose short-term effects was the replacement of gas-based generation for the far more expensive diesel (oil-based) generation (Figure 4.4). And the second cause was the lagging behind of electricity generation investment with respect to demand growth. As in most economies with privatised electricity provision systems, the electricity sector in Chile is highly regulated[40], and its virtuous functioning depends on a myriad of complicated norms (Joskow and Schmalensee, 1983). These norms include market design rules, and the most knowledgeable analysts thought the depression of generation investment was the result of these rules becoming outdated. The opinion of these analysists was that this market worked well through the 1990s, but became outdated by the 2000s, failing from then on to give investors appropriate investment incentives (Moreno et al., 2010; Rudnick and Mocarquer, 2006). This rosy view, however, puts all of the blame on the regulator and none of it on the established investors of the substantially concentrated Chilean electricity sector (CCTP, 2011). These investors likely benefited from the supply-demand mismatch, and the consequent price increase, that their unwillingness to build enough new generation capacity created. Benefitting from high barriers to entry to the capital-intensive electricity sector (Foxon et al., 2005; Nasirov et al., 2015), it was

[40] The literature actually refers to privatized electricity systems as 'de-regulated' ones, but it is simply not the case that the electricity systems they refer to are de-regulated. Electricity provision is one of the most regulated sectors of most economies.

difficult for them to become displaced by more dynamic new entrants. Arguably, it was thus not *just* outdated regulations but a combination of this and market concentration that led the established electricity supply-side to become passive.

Several interviewees[41] mentioned that the radical electricity price increases that came as a result of these two causes was one of the factors that most strongly benefited the rise of NCRE generation. In order to understand why this factor improved the conditions for alternative technologies, and did not *just* lead to more building of conventional power plants, one must remember that, although by 2013 the *average* Levelized Cost of Electricity (LCOE) of conventional technologies was still typically lower than the average LCOE of wind, solar or biogas generation, this LCOE could still vary a lot from project to project (Figure 4.8). This was due to changes in locational conditions, such as the availability of nearby fuel sources (in the case of thermoelectric and biogas-based power plants), or the presence of the right climate (in the case of wind and solar power plants). Thus, even though conventional generation was cheaper on average, there could still be many 'low hanging fruit' NCRE projects which could compete with conventional generation if electricity prices were high enough. And electricity prices indeed became very high, this not only compared to their past trend, but also to other countries: in 2008, the average electricity prices for industry in Chile were more than 50% higher those of OECD countries (IEA, 2012).

How did this affect the attractiveness of the opportunities through the germination periods? In the case of wind farms, those built around 2009 – the Wind take-off year – were by then enjoying prices as much as four times higher than what they were before the Wind germination period started in 1999, meaning four times more income in the most extreme cases. But in the case of solar PV systems, those built around the Solar take-off year of 2014 were by then enjoying prices probably no more than twice as high as they were at the start of the germination period in 2004, which is still much higher, but not as high as in wind. Moreover, although when Solar sector investors and projects started to arrive these prices were still high compared to the past decade and to the rest of the world, they were also in clear decline. Thus what the data suggests is that although the increase in the Chilean price of electricity was undoubtedly beneficial for both of these cases, it was a more significant factor for Wind than for Solar.

[41] PPUI83, PPGY34, PPYH83, PPWL66, and PPER35, among others.

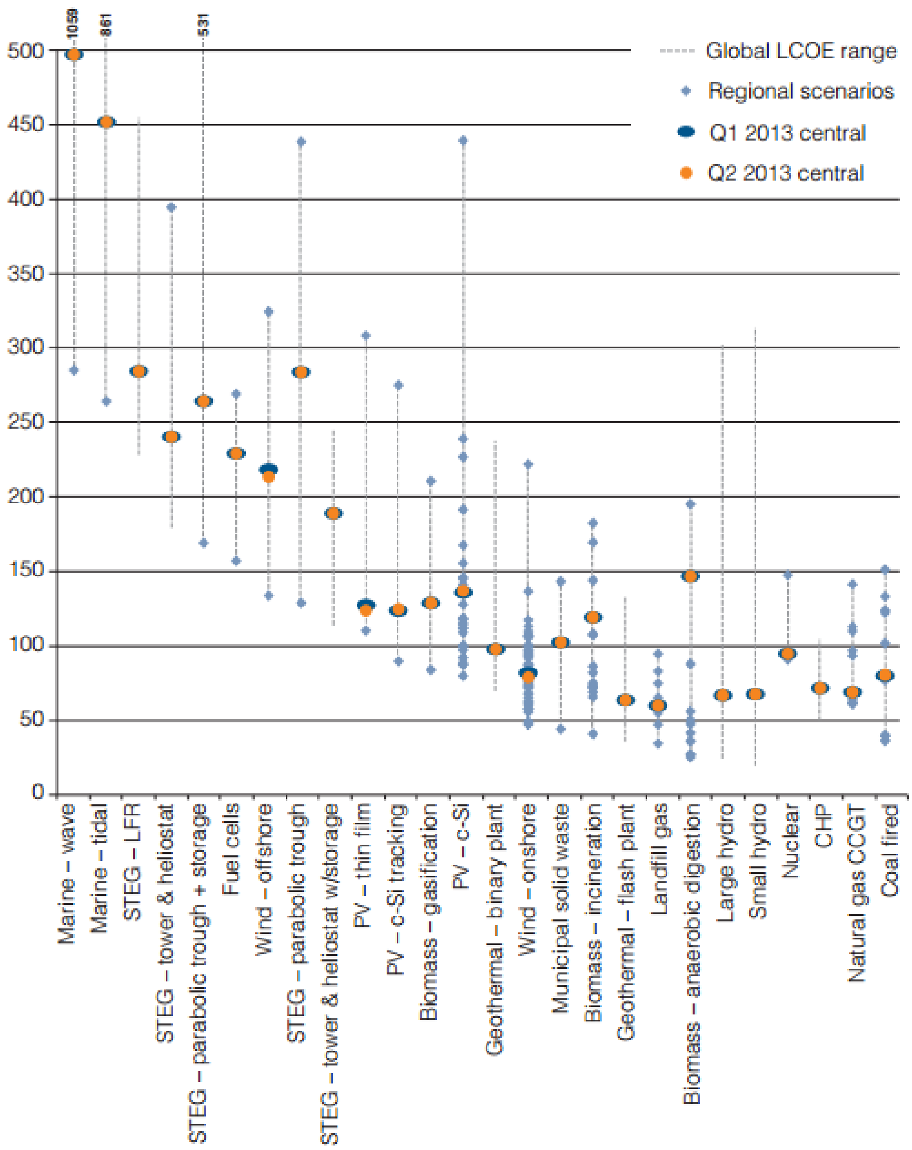

Figure 4.8: Levelized cost of electricity for various technologies in 2013. *The figure shows the high degree of variation in the cost of generating electricity with any given technology, chiefly due to variation in locational conditions such as fuel availability or climate. Source: World Energy Council, 2013.*

In the case of anaerobic digesters, the price difference from the beginning of the AD germination period in 1996 to its take-off year in 2006 was significant and on the rise. However, it took a while for electricity-generating anaerobic digestion projects to arrive: most of the early facilities in this sector were waste-treatment ones that flared – i.e. wasted – the biogas they generated (Figure 4.9). So although the price increase that started to take place after the first years of the AD germination period would certainly have led to a higher energy sales income if facilities sponsors' had used the biogas for energy generation, these choose not to do so. Remarks found on several of these projects' Clean Development

Mechanism Project Design Documents (CDM PDDs) suggest this was partly because, despite these high prices, the potential energy sales income was not high enough to justify the extra investments needed to add electricity generation components to anaerobic digesters. However, it was also likely because most of them had no previous experience and were unfamiliar with the complexities of the electricity sector[42]. Thus, in this case, this event did lead to an improvement in the context, but in the early years of this sector the improvement was simply not a big enough incentive to add electricity generation components to anaerobic digesters.

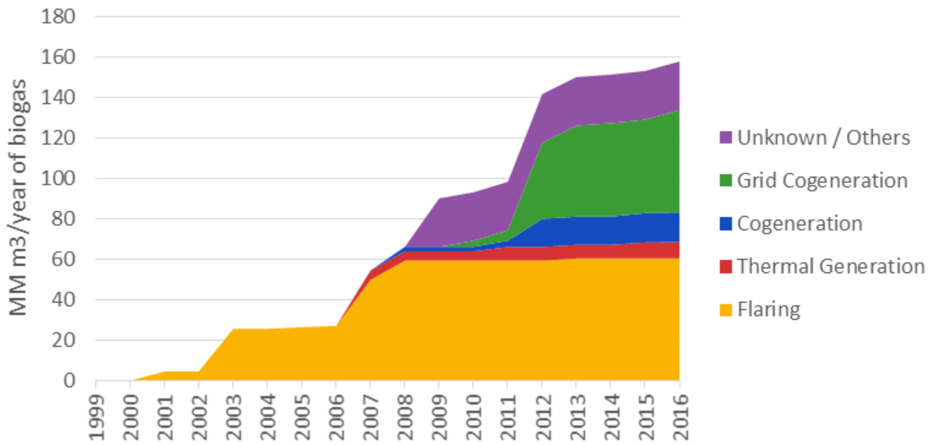

Figure 4.9: Use given to the biogas generated by anaerobic digesters. *Source: own elaboration; the numbers are only a rough, first approximation built from information on projects' environmental impact reports available at www.seia.cl, CDM project design documents available at cdm.unfccc.int, and various project-specific sources available on request to me.*

The rise in the price of Chilean electricity – which, as we just saw, was an important factor in some of the cases – was the result of the interaction of one common source of new entrepreneurial opportunities with domestic events that don't neatly correspond with any of the 'usual suspects'. On one side of this interaction was the sudden unavailability of gas, a fluctuating resource availability that, as the previous section showed, was not caused by

42 See for instance the CDM PDD of the Ramirana project, available at https://cdm.unfccc.int/UserManagement/FileStorage/CBJBBE4QYZMRIZAD1QHKKWQ1S30ZPZ: *This anaerobic and aerobic manure treatment process is one of the most advanced technologic systems in the world. Only few countries have implemented this alternative because of the high investment costs involved compared to other available systems and also due to subsidies for electric generation. The Chilean energy market does not give any incentives to sell biogas from these kinds of facilities into the grid. The investment involved in the production of energy by the utilisation of biogas is too high in the electricity market and is not profitable, compared to the electricity prices of generation in Chile.* (pp. 20).

global resource scarcities but rather by local geopolitical events (the Argentinian gas crisis). And on the other was the passivity of the established electricity supply sector, which did not keep up with the rising electricity demand because its regulations became outdated and its incumbents benefited from a concentrated market. This concentrated market made it possible for them to restrain new investments until they got a better regulatory deal without much danger of this causing them to be displaced by more dynamic new entrants.

4.2.3. The Clean Development Mechanism

One more event that affected the attractiveness of some of the opportunities was the CDM, the emissions trading scheme of the UNFCC Kyoto Process that became active in 2001. Figure 4.10 shows the number of Chilean projects registered on the CDM for the three sectors under study. This is shown along a simplified account of the evolution of the price of the Certified Emission Reduction Certificates (CERs), CERs that registered projects could get and then sell on the international carbon market. As one can see in this figure, the price of CERs – and with it the whole CDM – started to collapse after 2008, and had effectively collapsed by 2013. But, as we'll see below, before the scheme crashed it had a significant – though not a major – effect in the Wind and AD sectors. In these, the CDM made the entrepreneurial opportunities more attractive by the end of the respective germination periods than they were at the beginning, when there was no CDM. This was, however, not the case in the Solar sector, where the CDM had already crashed by the take-off year.

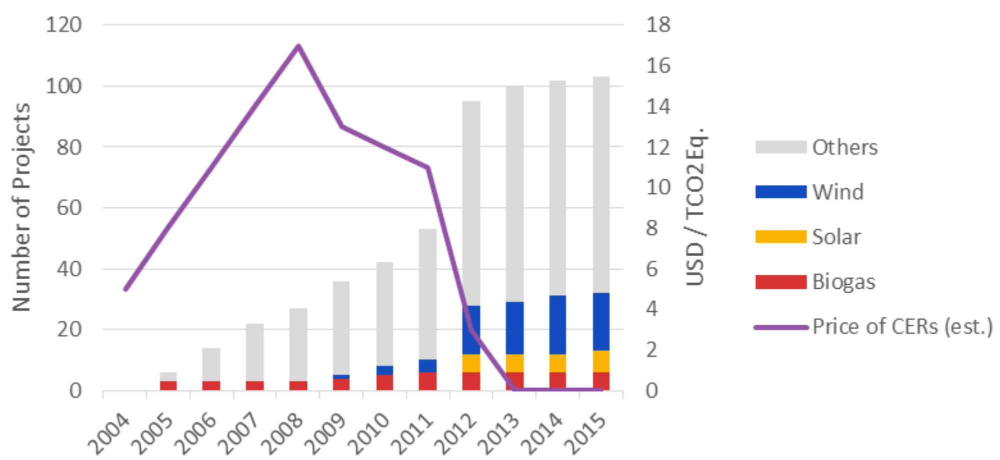

Figure 4.10: The Clean Development Mechanism in Chile. *Source: own elaboration based on a) self-compiled projects database and tabulated data generated by the CDM search facility, available at cdm.unfccc.int/Projects/ projsearch.html using search criteria "host country = Chile" (total number of projects by technology); b) World Bank (2012) and Zhou (2013) (price of CERS).*

In the case of wind farms, before the 2012 price collapse their sponsors could hope to gain a significant extra income from having these registered on the CDM. Assuming a wind farm could obtain 1,829 CERs every year per each MW of installed capacity[43], and assuming each CER could be sold at 10 USD, an 'average' 38MW wind farm[44] could hope to gain about 700,000 USD of extra income per year[45]. Assuming an average node price of electricity of 60 CLP/kWh (the lower bound of the price prevalent in the wind take-off year of 2009), a plant factor of 0.3 (a common figure for these facilities), and an exchange rate of 600 CLP/USD (close to that prevalent in these years), the energy sales income of the same wind farm – its main income – would be about 10 MM USD[46]. A wind farm, if CDM-registered, could therefore hope to get perhaps an extra 7% of revenues from the CDM, which is a sizable amount. Despite the very high transaction costs of CDM participation (Chadwick, 2006; Michaelowa and Jotzo, 2005), investors were clearly interested in this extra income, as five out of the eight projects built by 2011 – the end of this sector's germination period – were CDM-registered. Ironically, because of the 2012 CDM collapse, little of this income actually materialised. But by the time investors realised they weren't getting it, they had already made their investment decisions. Thus, the establishment and development of the CDM was an event that improved the attractiveness of the entrepreneurial opportunities of the Wind sector right from the beginning of is germination period, and ceased to do so right at its end.

The effect of the CDM in the AD sector was less straightforward than in the Wind sector. By the end of this sector's germination period in 2008, only three out of the nineteen facilities that had been built were CDM-registered. These, however, were not just any facility, but rather the very first ones built in the country, and also three of the largest ones. In their CDM PDDs[47], Agrosuper – the sponsor of all three facilities – made it clear that part of the reason why they included anaerobic digesters in their waste treatment systems was that they hoped the extra costs of this compared to alternative waste treatment schemes would be paid by CDM-income[48] – an income which they could expect to be even higher than that which wind farms could obtain per dollar invested. It is a fact that few other AD projects were CDM-registered after these three, probably because of the high transaction costs

[43] This estimate was built by dividing the sum of the registered reductions of Chilean CDM-registered Wind projects by the sum of those projects' installed capacities in MW.
[44] The average size of wind farms in Chile by 2016 was about 38MW.
[45] 1,829*38*10 = 695,020
[46] 38*1,000*24*365*0.3*60/600 = 9,986,400
[47] One may find these by searching for the words 'corneche', 'peralillo' and 'la estrella' at https://cdm.unfccc.int/Projects/projsearch.html
[48] They, however, had a vested interest in arguing this, for the CDM was meant to register only those projects would wouldn't have been built anyway without the extra incentive. But the fact that the project got registered meant that the CDM evaluators believed in what is called the 'additionality' of these projects.

required for CDM-registration made this economical only for the very large facilities. But, despite this fact – which would suggest the CDM was not, after all, so significant a driver in this sector –, it is conceivable that, had the CDM not been there, Agrosuper would have chosen a different technology. The CDM, therefore, proved to be a major incentive for just a few AD projects, but these projects were the crucial first innovations that showed the way for others through demonstration effects (Perez, 1983; Robertson, 1967; Schumpeter, 1939).

In the case of the Solar sector, there is hardly any basis to conclude that the CDM made solar PV systems more attractive entrepreneurial opportunities. The few solar projects that were CDM-registered were all registered in 2012, and all but one of them were sponsored by the same firm. These few instances were part of a rush to register projects before the end of 2012, which was reportedly[49] brought about by the passing of a European regulation mandating emission reductions from CDM projects registered after 2012 by middle-income countries such as Chile not to be recognised within this continent's emissions trading system. And, in any case, the really sizable investment decisions of solar PV system sponsors were taken after the CDM started to collapse, making it extremely unlikely that the mechanism had any effect on them.

The CDM was a system that changed the value of emission-reducing projects through the creation of a new institution and the passing of international regulations, and thus neatly corresponds with one of the commonly acknowledged structural change drivers: evolving policies and institutions. In this case, however, these changes had international origins.

4.2.4. The Renewables Obligation Law

One more significant change in context that took place in the period of interest was the passing, in 2008, of a Chilean national Renewables Obligation Law, and its subsequent update to make it more ambitious in 2010. The law obliged all energy generators to source a growing share of the electricity they commercialised from renewable energies: 5% of all new contracted energy from 2010 onward, escalating to 20% in 2024 after the law was updated in 2010. The obligation established a fine for non-compliance with this requirement, which generators could meet by generating their own renewable energy or by buying surplus green certificates from other generators (Araneda et al., 2010).

[49] By PPEJ83

Although the renewables obligation was a technology-neutral regulation, it didn't make much of a difference to the allure of solar PV systems or electricity-generating anaerobic digesters through the corresponding germination periods. Figure 4.11 provides evidence for this. The figure shows the total sales of green certificates from generators with a renewable energy surplus toward those with a deficit. One can see there that, from 2010 (the year the obligation came into effect) to 2014 (the last year for which data was available at the time of writing this), biogas-related transactions were insignificant, and solar-related transactions were non-existent. There were, in other words, no Solar or AD generators that sold surplus green certificates in the market. As said above, obtaining an extra income from the sale of green certificates was just one of two ways in which the law could have a positive impact on renewable energy generators: these, recall, may also use these certificates to comply with their own part of the obligation. There is no evidence, however, that Solar or AD generators did this: few, if any, of these facilities have been sponsored by generators with a deficit of green energy. Besides, in the case of AD facilities, even if the obligation had become an important incentive to add electricity generation components to the facilities, this would have been a change of context taking place after this sector's germination period. Thus neither solar generation, nor what little grid-connected biogas generation there was, was much affected by the Renewables Obligation.

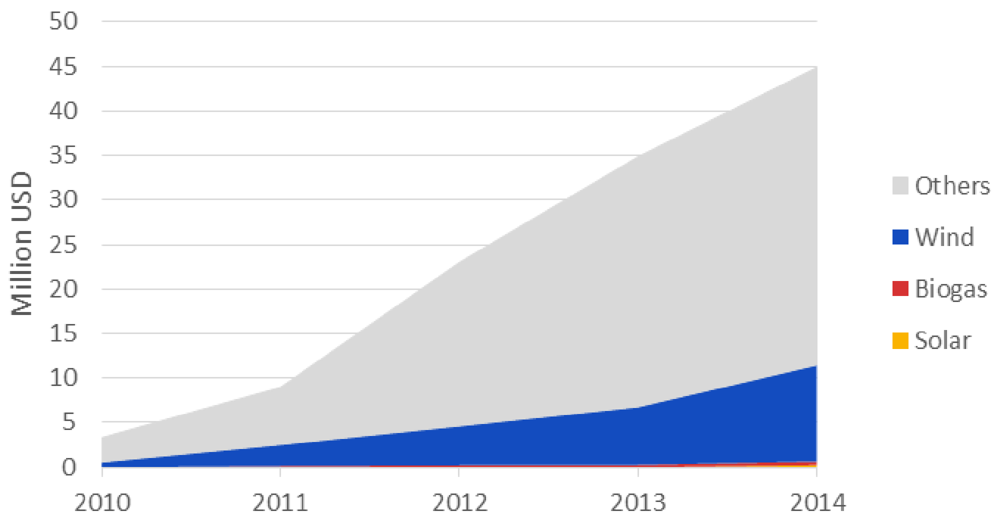

Figure 4.11: Accumulated flow of transactions in the Chilean green certificates market. *The Renewables Obligation legislation, which created this market, was passed in 2008 and came into effect in 2010. Most projects in the 'others' category are small-hydro or biomass power plants. Source: own elaboration based on tabulated data generated by the CDM search facility, available at cdm.unfccc.int/Projects/projsearch.html using search criteria "host country = Chile".*

The Renewables Obligation, however, did have a more significant impact in the Wind sector. As Figure 4.12 shows, some wind generators did get extra income from the sale of green certificates. One can see how large this income was by dividing the 10.84 MM USD of wind-related green certificate transactions that took place from 2010 to 2014 (Figure 4.11) among the wind farms that operated in this period, which were around 20. If one rounds the numbers, one gets that, on average, these transactions amounted to an extra 100,000 USD per wind farm per year. Recall from the previous section that the average electricity sales income of a wind farm is about 10 million USD. This means that, on average, the extra revenue from the CDM of the average wind farm was something like 1% of its normal energy sales income. This figure is not very large, and by itself does not suggest the obligation had a significant effect on the sector. However, some utilities in deficit did, in this case, generate their own Wind energy to comply with their part of the obligation (Figure 4.12).

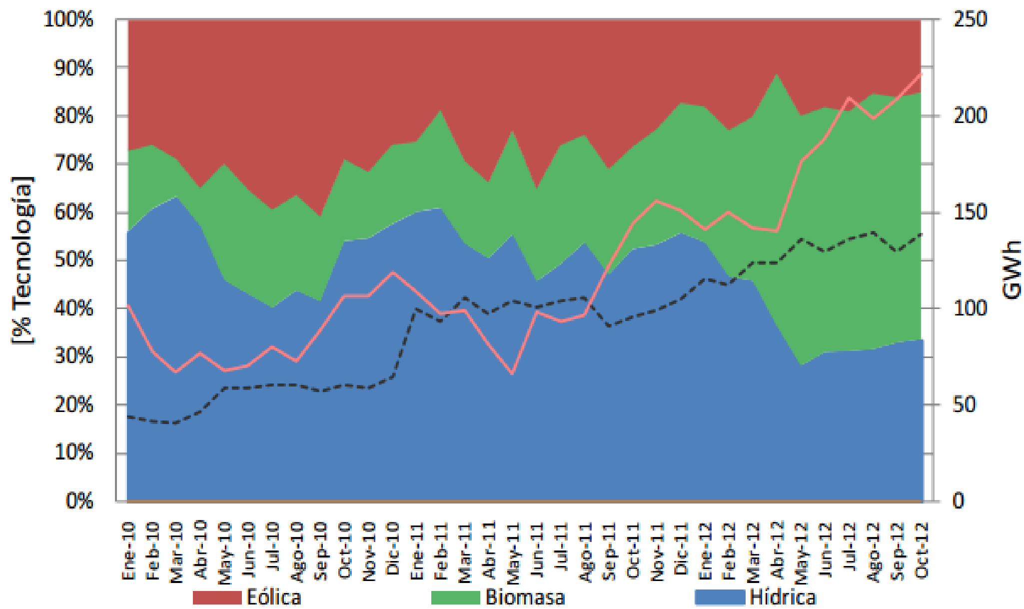

***Figure 4.12: Monthly* compliance with the renewables obligation by technology.** *Left axis, areas graph: percentage of the obligation met using wind (red), biomass (green) and mini-hydro (blue) technologies. Right axis, lines graph: the dashed line indicates the total amount of renewable electricity required by the obligation, and the red line indicates the actual amount of renewable electricity generated every month. Source: Olivares and Maldonado (2012).*

Figure 4.12 is also key to understanding the reasons why the obligation did not have a significant effect on the Wind and AD sectors – or, for that matter, a larger effect in the Wind sector. As it happens, the threshold established by the obligation – 5% of renewable electricity in 2010, gradually escalating to 20% in 2024 – was small in relation to the available NCRE generation capacity: the obligation, in fact, has largely been met with green certificates coming from mini-hydro and biomass (not to be confused with biogas[50]) power plants. However, it is also important to understand that the impact of the obligation may also have had a more indirect component: as reported by one knowledgeable interviewee[51], the regulation, in addition to its direct economic impact on the profitability of NCRE generation, sent a powerful signal about the government's commitment to supporting renewable energies, one which probably helped in attracting the various national and especially international investors that later entered this and also the Solar sectors[52].

The renewables obligation is an instance of the same commonly recognised structural change driver as the CDM: changing regulations and institutions. Though, in this case, the changes were not international but rather domestic, they were informed by similar developments taking place abroad.

4.2.5. The *Patagonia sin Represas* Social Movement

Above, we saw how Chile's electricity system is highly reliant on hydroelectricity. By the end of the past decade, it still seemed to be common and uncontroversial to argue that this would, and should, continue to be the case in the future. However, events that took place in 2010 relating to plans to construct a series of large hydroelectric dams in the rainforest-dominated far south of the country, led to a profound change in attitude towards this form of energy. In these years, conventional (dam-based) hydroelectricity came to be perceived as undesirable and unsustainable by a large majority of the population and by powerful political groups, thus depressing the prospects of one of the most significant competitors of non-conventional renewable energy sources.

At the heart of these events was the *Patagonia sin Represas* (Patagonia without Dams) social movement. This agglomeration of dozens of national and international NGOs and social groups mounted a formidable opposition against *Hidroaysen*, a joint venture among a domestic and an international utility that was 'preparing to build at least seven major hydropower dams, along with a 70-meter-high transmission line to transport power

[50] Though the biomass category in this graph includes biogas, it also includes wood burning and other such biomass-fired power plants, which were vastly more numerous and sizable than the single grid-connected biogas power plant existent back then. Thus the vast majority of the energy in this category is not biogas energy.
[51] PPHR26
[52] It is likely that the obligation also served to attract solar sector investors, but in this case other factors were so overwhelmingly more significant than it is unsurprising interviewees from this sector rarely mentioned it.

more than 2400 kilometres north to Santiago'. The power line alone was to require 'one of the world's biggest clear-cuts, a 120-meter-wide corridor through ancient forests – fragmenting ecosystems – and the installation of more than 5000 transmission towers' (Vince, 2010).

Although *Patagonia sin Represas* was active as early as 2007[53], the peak of its influence took place in the year 2010. In this year, massive protests of hundreds of thousands of people, demanding the plans to construct the dams be scrapped, took the streets of several Chilean cities. The formidable traction of the social movement that coalesced against the project – one 2010 poll assured that 80% of the population opposed the dams[54] – forced the government to deny *Hidroaysen* the environmental approval that it needed to be built. Apart from this direct impact, this decision had a major symbolic value. Like the Renewables Obligation sent a powerful signal about the government's commitment to non-conventional renewable energy, the decision to stop *Hydroaysen* sent a consequential signal about the lack of social support for this conventional energy source (Elgueta, 2012; Herrera et al., 2015).

Figure 4.13: An advertisement banner of the Patagonia Sin Represas social movement. *The text reads 'Our dazzling Patagonia. What savage would do this? Hidroaysén would'. The banner is one of many items from a large and lengthy protest campaign. Source: www.patagoniasinrepresas.cl/final/contenido.php?seccion=materiales*

The change in attitudes toward conventional hydroelectricity took place after the take-off of the AD and Wind sectors. Thus, although it undoubtedly affected the later development of these two, it cannot be assigned responsibility for their take-off[55]. However,

---

[53] web.archive.org/web/*/http://www.patagoniasinrepresas.cl/

[54] ambiental.unab.cl/etiqueta/ii-encuesta-sobre-percepcion-y-actitudes-hacia-el-medioambiente

[55] One interviewee from the AD sector (PPUX25), which was involved in the first large electricity generating anaerobic digester project in the country, remarked that 'at the time we would all be crossing our fingers so that Hydroaysen would be scrapped', indicating how this event was not

the evidence suggests that the event did significantly improve the context for solar PV systems in the lead up to this sector's take-off. With hydroelectricity having fallen into disfavour, the need for an alternative electricity sector development strategy became much more important, and after 2010 the government came under strong pressure to develop one such strategy. Because of their reluctance to embrace the will of the people, the first of the country's Energy ministers – the Energy Ministry was created in 2010, which shows how high on the political agenda this issue became in these years – lasted for only a few months, and six different people held the office from February 2010 to February 2012[56]. With the northern territory of the country being dominated by the Atacama Desert and its remarkable solar radiation conditions, the encouragement of solar energy was one obvious component of practically every single effort to develop such a strategy. And there were a number such efforts at the highest level since 2010 (CADE, 2011; CCTP, 2011; Ministerio de Energia, 2015). These developments were all very positive for the Solar sector, and no one involved or planning to be involved in the Energy sector could have been unaware of them.

Interestingly, the literature does not often acknowledge social movements such as the above as significant structural change drivers. Although, as we have seen, the literature widely recognises that evolving policies and institutions can become significant drivers, it is uncommon to find in these writings reflections about the role of social movements on directing this process of evolution. One significant exception are the writings of Acemoglu and Robinson (Acemoglu et al., 2004; Acemoglu and Robinson, 2013): because of their willingness to embrace the role of historical contingencies, these authors are able to acknowledge the role of collective action. And another exception is the literature on sustainability transitions, which has not neglected this issue in their systematic attempts to understand socio-technical change over long time periods (Geels, 2002; Markard et al., 2012; Smith et al., 2010).

4.2.6. The Cost of the Underlying Technologies

The discussion comes now to what was by far the most significant change of context taking place through the germination period of the Solar sector. Through this period, from 2004 to 2016, the cost of solar PV modules decreased by as much as 80% (Figure 4.14). These years, moreover, saw a price reduction not just of solar PV modules – which, by 2010, constituted about half of the cost of a solar PV system (IRENA, 2012) – but also of many of

irrelevant for these. The argument, to be clear, was that the event was not relevant *during their germination periods*.

56 https://es.wikipedia.org/wiki/Ministerio_de_Energ%C3%ADa_de_Chile

the other costs of these systems. From 2010 to 2014 alone, the LCOE of solar energy – i.e., the overall average cost of solar-generated electricity – 'was reduced from 44% to 54%' (IRENA, 2015). In other words, it was halved. The positive impact of these price reductions for the competitiveness of solar projects was extraordinary, and was even larger than the impact of the electricity price rise that also took place in these years.

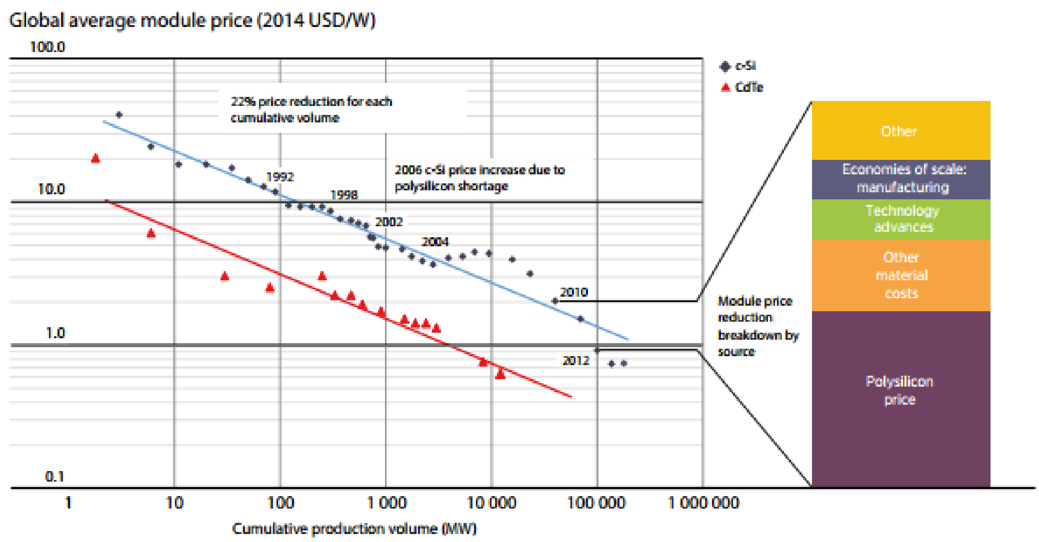

Figure 4.14: Price trends of solar PV modules. *The left axis is in logarithmic scale. Except for a short recovery in the years after 2004, prices have been decreasing exponentially since before the 1990s. The 2008 – 2012 fall was particularly rapid. Source: IRENA (2015)*

The causes of these price reductions had nothing to do with Chile. What drove the price of solar PV systems down was technological development in the advanced countries (which made solar PV systems far more efficient), and then the entry of China into solar PV module production (which, through production process improvements and economies of scale, made them far cheaper) (IRENA, 2015). The impact, however, was felt worldwide. By the middle of the 2010s, solar generation, in many places, became for the first time competitive against conventional technologies. Foremost among these places was the *Atacama Desert* to the north of Chile, which as we've seen has some of the best solar radiation conditions in the World. Domestic and, especially, foreign firms rushed to develop and sponsor projects once prices became low enough to compete with other technologies.

No similar underlying technology cost reductions took place through the Wind or AD germination periods. And in the case of Wind, aerogenerators, in fact, became more expensive. Driven by rising costs of materials, tight supply, and technological improvements which improved performance but also increased production costs (IRENA, 2015), the price of aerogenerators rose substantially from about 1999 to 2008 (Figure 4.15)[57] – i.e. right from the beginning of the Wind germination period until about its take-off year. Prices then slowly declined until about 2014, and then stabilised[58]. However, the level at which they stabilised was still higher than the lows reached in 1999. As the figure shows, from the beginning to the end of the Wind germination, prices increased by about 50%. And from their trough in 2001 to their peak in 2008, they increased by about 100%. Assuming that aerogenerators represent 70% of the cost of a wind farm – which was approximately the case in 2013, see IRENA, 2015, p. 57 – this led investment costs for wind farms to rise by 35% to 70%[59], depending on the period one considers.

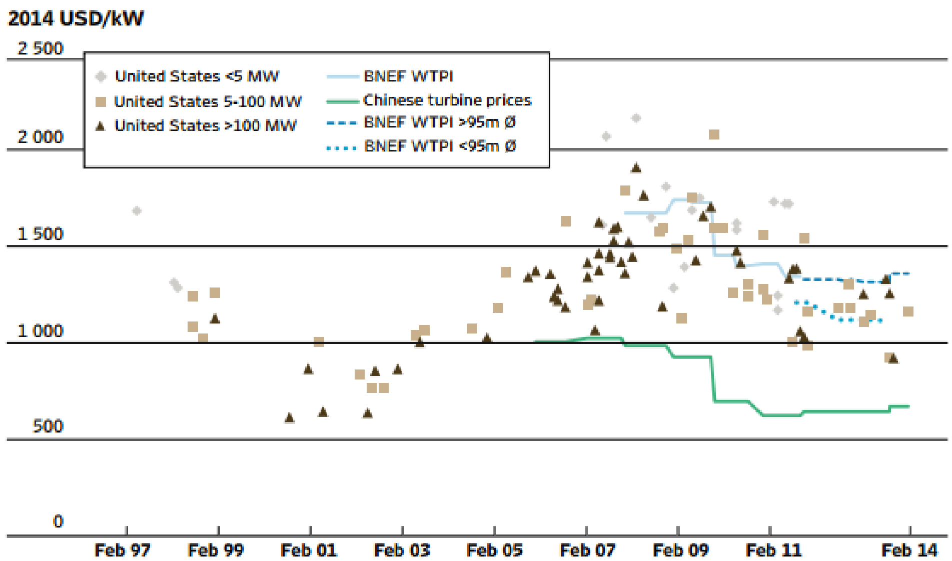

Figure 4.15: Price trends of aerogenerators from 1997 to 2014. *Before the 2000s, prices were rapidly falling, but from about 2000 to 2008 they increased. After 2008 they fell again, but by 2014 they had stabilised at a higher level than their trough in 2000. Source: IRENA (2015)*

---

57 According to IRENA, this rise was due to "... three components. First of all, it followed the rising costs for materials (e.g. steel and cement), labour and for civil engineering. Secondly, tight supply drove up prices and allowed higher profit margins for wind turbine manufacturers, who started receiving more orders and struggled initially to meet new demand. Finally, technology improved; wind turbine manufacturers introduced larger, more expensive turbines, with higher towers and more capital-intensive foundations, but which also achieved higher capacity factors." (p. 59)

58 Incidentally, the 2009-2014 decline in wind prices is probably the reason why, in terms of aggregate capacity, wind investment more or less stalled from about 2009 to about 2012. Prices going down, it made sense for investors to wait until these had reached the valley to make their investments, especially if these investments were very large.

59 100% cost increase of a component which is 70% of the total cost of the project = 70% increase in the cost of the project; and 50% cost increase of a component which is 70% of the total cost of the project = 35% increase in the cost of the project; this of course assumes that the cost structure of wind farms stays constant, which is not an unreasonable first approximation.

In the case of the AD sector, the cost of building non-electricity-generating anaerobic digesters was far less dependent on cost reductions in capital goods. This was largely because these facilities are, for the most part, civil works that use standard materials (concrete, steel, etc.) and low or medium-tech capital goods (pumps, valves, etc.) which are not experiencing rapid technical change. AD technology is, moreover, fairly mature (Mata-Alvarez et al., 2000). Thus, the commercial success of anaerobic digesters was more dependent on their design being well adapted to the context, and on their being operated soundly, than on variations in the price of the capital goods that went into their construction. And much the same was the case for the electricity-generating ones: although the cost of these does depend on the price of somewhat more expensive capital goods, such as motors and rectifiers, these are also capital goods which are not currently experiencing rapid technical change. Hence, biogas-based electricity generation is not expected to become much cheaper in the foreseeable future (Figure 4.16). The cost of the key inputs that go into anaerobic digesters, then, did not significantly vary through this sector's germination period and did not, therefore, constitute either a positive or a negative change in context.

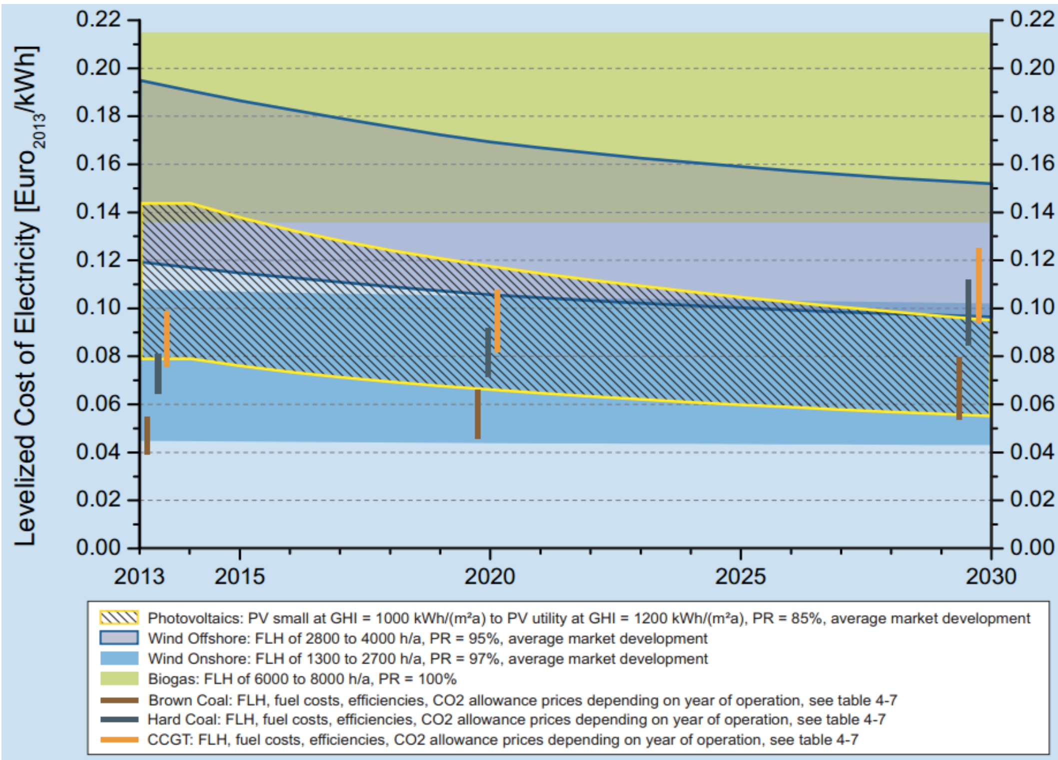

Figure 4.16: 'Forecast for the development of LCOE of renewable energy technologies as well as conventional power plants in Germany by 2030'*. Source: Kost et al. (2013)*

Technical change, as we have seen, is widely regarded as one of the main structural change drivers. In fact, of all the 'usual suspects', it is probably the one whose significance is most widely acknowledged (Krüger, 2008; Perez, 1983; Silva and Teixeira, 2008). In the long run, it is clear that all three cases have benefited from technical change in their underlying technologies. However, as the evidence shows, in the twelve-year time frame that we are focusing on, it was only in the Solar sector that technical change significantly improved the attractiveness the underpinning entrepreneurial opportunities.

4.2.7. The New Electricity Auctioning Process

The next turn in context was one that strongly played in favour of both the Solar and Wind sectors, but which came several years after the latter's take off year and thus cannot be said to have been a factor in its ignition. The event was a regulatory change that significantly eased the commercialization of renewable energy. Indeed, it was a tailor-made regulation designed to foster the development of wind and especially solar electricity by dealing with one of their main shortcomings: their intermittency.

To comprehend the importance of this regulatory change, it is necessary to understand the design of Chile's electricity market and its implications for an intermittent energy source such as solar, which can only provide electricity during daytime. Electricity generation utilities (generators) in Chile have two main commercialization options. The first is to sign Power Purchase Agreement (PPA) contracts with large energy consumers such as electricity distribution utilities (distributors, the most important large energy consumers) or sizable mining firms. For the most part, PPA's are call/option contracts in which the energy consumers acquire the 'option' to 'call' for variable amounts of electricity from contracted generators according to their fluctuating consumption needs (up to a maximum level of power). The generator must fulfil this request with electricity from its power plants and is paid a pre-agreed price for this, which gives it a degree of security about its long-term income.

The generator, however, does not get to decide when its power plants are turned on: it is the independent system operator (operator) who instructs power plant operators to turn these on and off, following a lowest-variable-operation-cost-comes-first rule[60]. Simplifying, the rule obliges the operator to prioritise wind and solar generators (which have zero variable operation costs), then hydroelectric generators, then gas-based and carbon-based thermal generators, and finally diesel-based thermal generators (which have

[60] A rule which is subject to technical and other restrictions which sometimes lead to significant deviations

the highest variable operation costs). If the power plants of a generator are not generating sufficient electricity to provide for its contracted demand, it must buy the deficit from other generators, those whose power plants are generating a surplus. The sales of electricity among generators conform what is called a SPOT market, which is managed by the operator. This operator calculates the price of electricity by the hour based on the variable operation cost of the plant with the highest cost operating on any given hour. At the end of each month, the operator processes its data to calculate the transactions among generators, and tells everyone how much they have to pay to each other.

The second commercialization option for electricity generators is to sell directly to the SPOT market. Selling directly to the SPOT market is much riskier than selling through the signing of a PPA. This is because, while a PPA assures generators a pre-agreed price, the SPOT market doesn't, and prices in this market fluctuate wildly: while at some points of the day they can be zero (e.g. when all electricity is being provided by renewables), at other points they can be several times the average (e.g. when the operator needs to instruct expensive diesel generators to be turned on). If a generator that sells to the SPOT market is instructed to turn its power plants on while the prize is zero, it gets no income for the power it generates. And, if it is instructed to turn them on when the prize is high, it can get a very high income. Since the generator can't know in advance, it is exceedingly difficult for it to calculate its long-term income. This is what makes this market highly risky.

Because of the above, conventional generators normally prefer PPAs than selling to the SPOT market. However, before 2013, PPAs were as risky as was selling to this market for intermittent generation sources such as solar. The reason for this was that clients could 'call' for their contracted energy at any time during the day. Solar generators, however, would never be able to meet their contracted obligations while the sun was not shining. This meant that, even if they had PPAs, they would be exposed to the SPOT market for more than half of the day.

However, in 2013, these electricity commercialization rules were updated in a way that greatly favoured intermittent electricity sources in general and in particular solar. On this year, the regulator agreed with the energy distribution companies that, from then on, electricity auctions – which take place regularly and are organized by the regulator – would include a sizable number of hourly energy blocks, meaning that energy generators could now make offers to provide for blocks that were circumscribed to certain parts of the day only. From the moment this new auctioning process was implemented for the first time in the second auction of 2013, solar generators could bid for blocks of energy that went from 8:00 am to 17:59 pm, i.e. while the sun was shining (or, in the case of Wind, when the wind was blowing). Solar generators who were awarded these contracts would not have to worry anymore about exposition to the SPOT market, for they could now be certain that they would not be requested electricity on the hours of the day when they could not provide it.

This made a large difference, as changes quickly confirmed. Of the 20 different generators that were awarded contracts in the first auction under the new rules, 5 were new solar generators (Figure 4.17). These generators could now compete on a par with their conventional counterparts. Even more, having been freed from the risks of SPOT market exposition, they were able to offer prices which were lower than those offered by conventional generators (INODU, 2014). Things would stay the same for the auctions that would come, making life much easier for renewable generators in general, and for solar generators in particular.

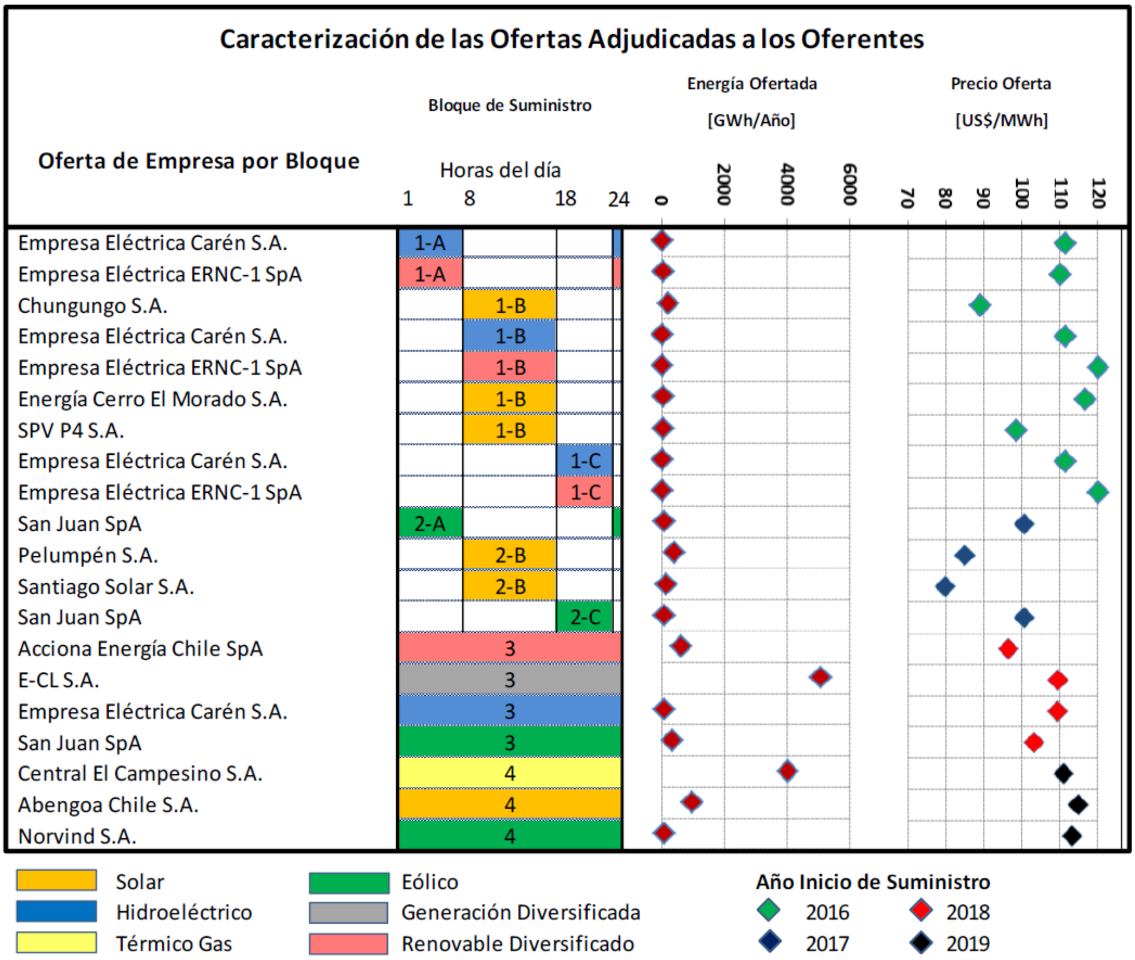

*Figure 4.17: **Summary of the results of the 'SIC 2013/03 2º llamado' electricity auction.** The auction was the first that took place under the new electricity auctioning process. Five solar and two wind projects won hourly-block contracts. Before the change of rules, generators could only bid for full-day provision. Source: INODU (2014).*

4.2.8. The Regulatory Tightening of Environmental Standards

The one remaining event was one that only affected the AD sector. The evidence, though, suggests that this was the most significant factor in this case. The event was a regulatory change – or more correctly a series of them – that affected waste treatment practices, and through this the attractiveness of the entrepreneurial opportunities that underpinned this sector.

Since 1994, the cornerstone of Chile's current environmental regulation has been the *Ley de Bases Generales del Medio Ambiente*. This law set the general framework for an environmental governance system that was a major advance on past practices. The law established, for the first time, legal definitions for concepts such as 'biodiversity', 'pollution' and 'environment', and empowered the state to demand more stringent environmental management standards from economic agents undertaking activities that imposed environmental externalities. The law also created the SEIA, the government organ that became responsible for evaluating and deciding whether to approve projects with potentially high environmental impacts (del Favero, 1994).

The passing of the 1994 law, however, was just the beginning of the build-up of Chile's environmental governance system. On the matter of liquid residue management – which is the kind of waste treatment problem to which anaerobic digesters can provide a solution to – further legislations and policies were passed and implemented in 1998 (liquid residues sewerage discharge norm), 2001 (liquid residues ocean discharge norm), 2003 (liquid residues underground discharge norm), 2007 (mining residues discharge norm), 2010 (water treatment plant sludge management norm), and 2012 (fruit and vegetable industry sludge management norm). As the system was gradually strengthened, firms found it increasingly difficult to get away with polluting practices.

Arguably, it was mainly these higher standards that, in several cases, led firms to construct anaerobic digesters. The strongest evidence for this comes from two sources. The first are the *Environmental Impact Assessment Reports (EIA Reports)* submitted for some anaerobic digestion projects developed through the study period. Many of these reports, which are available to be seen online through the SEIA website[61], state the reasons why sponsors decided to build the corresponding facility. A web crawler that I coded for this study went through the reports on this site and found a reference in 26 out of 61 biogas projects to a policy known as *Clean Production Agreements*. These agreements were one of the main instruments used by the government to make firms improve their environmental

[61] www.sea.gob.cl

standards, and the fact that they were so often mentioned shows that it was in large part because of them that they had decided to upgrade their waste treatment processes through the building of anaerobic digesters. For example, one document stated that[62]

> *...the constant improvement policy of Agrícola El Monte S.A. was consecrated through the subscription in December 1999 of the first Clean Production Agreement among the swine industry and the regulatory authority...*

showing how the firm, like many others, was improving its environmental practices as a result of signing these agreements. Similar statements were found on other reports[63].

The second source of evidence about the significant effect of the regulatory tightening of environmental standards on the attractiveness of anaerobic digesters also comes from a set of documents. This time, these are the PDDs of the handful of anaerobic digesters that were CDM-registered[64]. These also made conspicuous reference to the *Clean Production Agreements*. It is unlikely that, had these policies not been implemented, firms would have improved their environmental standards by their own accord, for this had high costs and would have most likely had a negative impact on their profit rates.

The regulatory tightening of environmental standards that improved the context for anaerobic digestion facilities is one more instance of the commonly recognised structural change driver that we've already encountered a few times. The evolving regulations, in this case, were technology neutral, for what they demanded was that firms improve the quality of their waste treatment processes, not that they do so using anaerobic digesters. Anaerobic digestion, however, was one waste treatment technology able to treat waste to these more stringent standards, and these facilities were used for this purpose on several occasions.

---

[62] seia.sea.gob.cl/documentos/documento.php?idDocumento=1277724; own translation.

[63] See, for instance, the following statement in the report from the 'Santa Rosa' biogas waste treatment project by Agrosuper, from 2004 (own translation): 'The treated residues will be used as irrigation water ... in conformity with what was stipulated ... within the framework of the first swine Clean Production Agreement'. And again the following statement from the report of the 'La Gloria' project by Agricola AASA from 2013, which is ten years later, showing that the CPAs were not just a driver at the outset but throughout the AD story (own translation): 'Agricola AASA, under the framework of the CPA for the swine sector, has acquired the compromise of undertake a series of actions leading to the improvement of its environmental standards ... one of the most significant of which is the appropriate management of swine manure'.

[64] All of these are available on https://cdm.unfccc.int/Projects/projsearch.html by searching using the following project ref. numbers: 0031, 0032, 0033, 0457, 1919, 3924.

4.3. The Big Picture

In the last section, we saw how, in each case, there were a number of events that significantly altered the attractiveness of the entrepreneurial opportunities from the beginning to the end of the respective germination periods. The section, however, was organised around these various events, and not around the three cases. Our goal in this section is to put the pieces back together and arrive at a synthesis of the evolution of the context through these years.

As we do this, we will address two specific aspects of the germination periods. First, we will weigh the relative significance of the various events that were relevant to each sector. Among other things, this will allow us to understand which, if any, of the 'usual suspects' was the more relevant in each case, and the extent to which factors that do not neatly correspond with these last were also significant. And, second, we will ponder the degree to which these events, overall, made the opportunities more or less attractive by the end of this period than they had been at the beginning.

In undertaking these tasks, one difficulty that we will need to confront is that the nature of the issues, and the quality of the available data, make it exceedingly difficult to reach definite conclusions about many of these matters. These limitations, however, need not lead to the extreme of rejecting the possibility of reaching *any* conclusions at all. The middle ground that is within our means consists in reaching *tentative* conclusions. In many cases, these won't settle the matter, but as long as we don't lose sight of their tentative nature, they will be worth making.

4.3.1. Wind Farms

The most significant events affecting the attractiveness of the Wind sector's entrepreneurial opportunities through its germination period were the increase in the price of electricity, the Renewables Obligation, the CDM (all positive changes), and the increase in the cost of the underlying technologies (the most substantial negative change in this case). Except for the Renewables Obligation, the direct economic effects of these events were not difficult to quantify. What the calculations show is that the more than doubling of energy prices that took place through the period was a far more significant positive development than the establishment of the CDM: as we saw, while the CDM only brought around 7% of extra income of wind farms, the rise in energy prices may have even doubled it. The evidence also suggests that the increase in electricity prices, alone, more than compensated for the increase in the cost of aerogenerators: as we also saw, this latter negative development made wind farms from 35% to 70% more expensive through the germination period. Thus, of the three quantifiable factors, the rise in the price of electricity had by far the biggest impact, followed by the increase in the cost of aerogenerators, and then by the CDM. The overall effect of these three changes alone was clearly positive, and substantially so. But the effect was even bigger if one considers the Renewables Obligation. Although the impact of this latter development a) was, in principle, less direct because the policy was technology neutral, and b) in fact faded rapidly when the obligation started to be met with mini-hydro and biomass generation, the fact that the Wind sector took off just one year after the policy was passed, and that during its first years (2010 - 2011) a substantial share of the obligation was met with wind energy, suggests that its establishment may have been an important triggering event, giving a significant initial push to this sector.

In sum, the evidence suggests that building wind farms to generate electricity was a significantly more attractive entrepreneurial opportunity around the end of the germination period of the Wind sector (2011) than at its beginning (1999). However, as we saw in Section 4.1.1, one wind farm was built very near the start of this period: the *Alto Baguales* project. Interestingly, this project seems to have been a very successful one: Moreno et al. (2006) report that its plant factor was 0.39, which was higher than that of any other wind farm operational in Chile by 2015: these, as we've seen, averaged about 0.19 for first generation wind farms and 0.29 for second generation ones. As one interviewee – which had been involved in the project – noted as he spoke about the reasons for its success, this was largely because of the excellent wind conditions of the site where it was built[65]. The reason why the success of *Alto Baguales* is interesting is that it shows that, even though things improved greatly over time, generating electricity using wind farms was not an altogether unattractive entrepreneurial opportunity at the beginning of the Wind germination period: there were at least some contexts in which these could be good business. It is thus possible that, had this sector benefitted from a stronger entrepreneurial function, it would have taken off much earlier. Even though the opportunities would not have been as inviting, they may have been good enough.

Regarding the extent to which these events correspond with the most widely acknowledged structural change drivers, the picture is mixed. Changes in consumption preferences were not a significant proximate factor in this case. Technical change was also not a crucial factor: although aerogenerators did experience incremental technical changes through the period, these did not lead to a game-changing improvement in the

[65] PPHR82.

competitiveness of the technology[66]. Fluctuating resource availabilities, in the form of the Argentinian Gas Crisis, were on the other hand part of the reason for the rise in the price of electricity, a crucial event for this sector; and they were also, in the form of rising costs of materials, part of the reason for the increase in the cost of aerogenerators. And evolving regulations, in the form of the establishment of the CDM and the Renewables Obligation, were in this case also very important. Thus, the 'usual suspects' did play a very significant role as a group, but individually they were not all present. However, two of the events do not seem to correspond with any of these commonly acknowledged drivers: the passivity of the established Chilean electricity generation sector, which was one of the key reasons for the rise in the price of electricity; and the protracted supply shortage in the international aerogenerators market, which, as we saw, was one of the three main reasons for their 1999-2008 price increase. It is interesting to note that, although these factors were temporary[67], they *did* arguably lead to long-term consequences: once established, the Wind sector was able to grow despite the fact that the attractiveness of its underpinning entrepreneurial opportunities was diminishing[68]. This shows how, as argued in (Arthur, 1994; David, 2005), structural change is a path-dependent process whose trajectory is not *just* determined by economic conditions[69], but also by historical events with long-term consequences.

4.3.2. Solar PV Systems

As with Wind, the appeal of the entrepreneurial opportunities of the Solar sector was affected by several different events taking placed through its germination period: the rise in the price of electricity, the *Patagonia sin Represas* social movement, the fall in the cost of the underlying technologies, and the new electricity auctioning process. In this case, all of these events were positive for the opportunities and therefore the sector, but not to the same degree. Here, again, the direct economic effects are not quantifiable for all factors. Despite this, however, everything suggests that the radical decrease in the cost of solar PV

---

[66] Like they did in the case of Solar, probably because of better technological opportunities associated with its lesser degree of maturity. As we saw in footnote 41, technical improvement of aerogenerators made these more efficient but also more expensive. This period, furthermore, must also have seen some technical improvement of competing conventional technologies. These factors significantly dampened the economic effect of technical change in this sector.

[67] With post 2010 regulatory change and the entry of competition from renewable energy generators, the established supply-side sector did start to invest again; and with the end of the commodities boom, the 2008 recession, and the entry of new aerogenerator manufacturers, prices did drop from 2009 onward

[68] Diminishing because of a) falling electricity prices, b) the use of mini-hydro and biomass rather than wind generation to comply with the renewables obligation, and c) the collapse of the CDM – all factors which, arguably, were not compensated by the decrease in the price of aerogenerators that took place from 2008

[69] What Geels calls 'landscape' conditions (Geels, 2002).

system components was by far the most significant factor. This change alone meant building solar PV systems at the end of the germination period cost substantially less than half of what it had cost at its beginning (Figure 4.14). Moreover, developers and sponsors could be more or less assured that, unlike some of the other factors, this one would likely be permanent, for there was no reason to believe that the price of solar PV systems would go up in the foreseeable future: in fact, there was good reason to believe it would fall further (Figure 4.16).

Which factor should go next in relative significance is very hard to ascertain. The 50% increase in electricity prices that took place through the Solar germination period (Figure 4.7) was an unquestionably large boost. But though not commensurable with this last factor, the creation of a tailor-made niche market for intermittent electricity sources, through the establishment of the new electricity auctioning process, was also clearly important: the excellent performance of solar sponsors in the first auction suggests this. And the same happens with the *Patagonia Sin Represas* social movement. Although the effect of this movement was less direct than that of any of these last two factors, it was at least in part because of it that the Government became a strong supporter of renewables and implemented policies like the new electricity auctioning process to favour then. And this was in addition to the other great outcome of this social movement, namely the falling into disfavour of large-scale hydroelectricity, which could have otherwise become a formidable competitor. There appears to be no solid foundation for concluding which of these other three factors was the most relevant in this case.

Overall, the effect of these changes was not just clearly positive: it was also extraordinarily large. Far larger, in fact, than the changes that took place through the germination period of the Wind sector. Generating electricity using solar PV systems was an enormously more attractive entrepreneurial opportunity by the end of this sector's germination period than it had been at its beginning, when electricity prices were 30%-40% lower (Figure 4.7), there was no explicit policy support and no tailor-made auctioning process, hydroelectricity had not fallen into disfavor, and – most importantly – building power plants that used this technology was substantially more than twice as costly (Figure 4.14). Considering that, in most places, the LCOE of Solar energy has only recently started to catch up with conventional generation (Figure 4.8), there is little basis to believe it could already have been competitive at the beginning of this sector's germination period, as may have been the case with Wind. In consequence, there is no reason to conclude that what prevented this sector from taking off ten or more years earlier – i.e. before the start of its germination period – was a lack of entrepreneurship. In this case, back then, the underpinning innovations were just not attractive entrepreneurial opportunities.

As happened with the Wind sector, the main proximate determinants of the attractiveness of the opportunities underpinning the Solar sector only partly correspond with the most widely acknowledged structural change drivers. And here again these last are not all present. As with Wind, changes in consumption preferences played no role here. Technical change, on the other hand, was crucial, for as we saw technological development was the main reason behind the dramatic decrease in the price of solar PV systems that took place in these years. Fluctuating resource availabilities were also important in this case, for Solar was too affected by the rise in the price of electricity which was partly caused by these. As we saw, however, this increase in prices was also partly caused by the passivity of the established supply-side sector, which does not fit any of the 'usual suspects'. Finally, evolving policies, in the form of the new electricity auctioning process, were also crucial here. However, it is interesting to note that these regulatory changes came at least partly as a result of social pressure, which is not often acknowledged as a significant structural change driver: as we saw, the *Patagonia Sin Represas* social movement was crucial in driving support for renewables energies up on the government's agenda – not to mention its other NCRE investment encouraging effects.

4.3.3. Anaerobic Digesters

In the case of the AD sector, several factors – mostly positive ones – changed the attractiveness of its underpinning entrepreneurial opportunities from the beginning to the end of its germination period: the rise in the price of electricity, the development of the CDM, and the regulatory tightening of the country's environmental standards. However, only the last of these can be said to have been a consistently significant factor: while electricity-generating AD facilities came only after the AD germination period had ended (Figure 4.9), and CDM-registered AD projects were an early but small minority (Figure 4.10), the tightening of waste-treatment standards took place throughout, and, as we saw, was a significant incentive to build AD facilities. Unless CDM-registered or electricity-generating, these facilities would moreover not generate a direct income, and would therefore not likely be built if there was no obligation to do so. It is thus likely that this last factor was the most significant of the three. And, because of the timing issues just mentioned, it is likely that the CDM was more significant than the rise in the price of electricity. This last factor, in effect, proved significant for a second generation of projects only, the generation that came after the germination period, and that saw the first electricity-generating digesters be built.

The magnitude of the positive effect of these factors in the allure of the opportunities is somewhat harder to ascertain than in the previous two cases. This is because, in this case, the effect of what seems to have been the most relevant factor is not as easily quantifiable. As we saw, however, it is likely that few anaerobic digesters would have been built in the absence of regulatory pressure to do so, for firms rarely take charge of mitigating their negative environmental externalities if they are not made to do so. Thus, although building anaerobic digesters to treat waste – and, in some cases, generate some CDM or electricity income from the process' by-product – was a more attractive opportunity by the end of this sector's germination period than it had been at its beginning, it is difficult to say by how much.

As with the two previous cases, the correspondence among these factors and the most widely acknowledged structural change drivers is significant but partial. Although neither changing consumption preferences nor technical change seem to have played a significant proximate role here, evolving policies (in the form of the regulatory tightening of environmental standards and the CDM) and fluctuating resource availabilities (which partly caused the rise in the price of electricity) did. The rise in the price of electricity, however, also had causes not often acknowledged as significant structural change drivers, as mentioned above.

4.4. Contrasts

Our next task is to go through the various events that we've discussed above and analyse them in terms of the internal developments vs. external influences and technology-push vs. demand-pull distinctions. As we've seen, the first of these contrasts is interesting because it touches on issues around the degree of autonomy of structural change processes. And the second is the topic of an old debate about the drivers of innovation by scholars in this area (Dosi, 1982a; Nemet, 2009; Rosenberg, 1994) – a debate which would be usefully informed by fresh results coming from the relatively under-research infrastructure sectors.

Looking through the lens of the first of these contrasts, the events that changed the context through the respective germination periods were a balanced combination of internal developments and external influences (Table 4.1). The rise in the price of electricity, to start with, was the result of the confluence of an external influence – the Argentinian Gas Crisis – and two internal developments – regulatory attrition, and the passivity of the established supply-side. The establishment of the CDM, on the other hand, was fully an external influence. The Renewables Obligation was, by contrast, an internal development, although one that was clearly inspired by similar laws that had previously been passed in foreign countries. And the *Patagonia Sin Represas* social movement was also, for the most part, an internal development, though again here one can find several traces of external influences, such as the participation of some international NGOs and the more diffuse ideological influence of the worldwide environmental movement. The evolution of the cost of the underlying technologies in these years – which, as we saw, was positive for Solar, negative for Wind, and neutral for AD – was in all cases a fully external influence. And, like the Renewables Obligation, the new electricity auctioning process, and the regulatory tightening of environmental standards, were both internal developments.

	Int. Developments	**< Combination >**	**External Influences**
Wind	*Renewables Obligation*		
Wind			*Cost of Wind Technology*
Solar			***Cost of Solar Technology***
Solar	*Patagonia Sin Represas*		
Solar	*New Auctioning Process*		
AD	***Env. Regulation Changes***		
Wind and AD			*Clean Dev. Mechanism*
Wind, Solar and AD		***Price of Electricity***	

Table 4.1: Relative significance of germination-period internal developments and external influences for the attractiveness of the entrepreneurial opportunities. *The bold texts indicate the most significant events. The table encapsulates my own judgements about the categorization and relative significance of the events, and is, therefore, subjective. My judgements, however, were based on the objective data presented in Section 4.2.*

What matters, however, is not how many of the events were of each kind, but rather the overall weight of the types of factor, for as we saw not all events were equally significant. In this regard, neither internal developments nor external influences were clearly dominant in the Wind sector. The main event in this case – the rise in the price of electricity – had internal and external causes. And, although the CDM and the changes cost of the underlying technologies were both external influences, it is not clear whether they had a bigger effect than the Renewables Obligation, which was fully internal. Entrepreneurial opportunities in the Solar sector, on the other hand, seem to have been more affected by external influences. In this case, the most important factor (the fall in the cost of the technologies) was fully external. Although the other factors were partly (price of electricity) or fully (*Patagonia Sin*

Represas and new auctioning process) internal, the importance of this fall in prices was overwhelmingly large and probably leans the balance toward the external influences. Finally, the opportunities in the AD sector seem to have been more shaped by internal developments than by external influences, for here the main event (tightening of environmental regulations) was fully internal, the next one in line (CDM) was external but not as significant, and the last one (price of electricity) was mixed.

Unlike the distinction made above, the technology-push vs. demand-pull distinction is one that only makes sense for factors that affected the attractiveness of the entrepreneurial opportunities in a positive way. Therefore, in making this second contrast, we leave the rise in the cost of wind technology – a negative development for this sector – out of the analysis. With this in mind, we can say that most of the events that improved the opportunities through the respective germination periods were of the demand-pull type (Table 4.2). All of them, in fact, except for the evolution in the cost of the underlying Solar technologies. Again, however, what matters is not how many events were of each type but rather their overall weight. If this is taken into account, there is still no question that, in the cases of the Wind and AD sectors, demand-pull factors were dominant, for technology-push factors were in both cases absent. In the case of the Solar sector, however, the situation is the opposite: here, the overwhelming significance of the drop in the price of solar PV system components means that, although demand-pull factors were important, technology-push ones were even more so.

	Technology-Push	**< Combination >**	**Demand-Pull**
Wind			*Renewables Obligation*
Solar	***Cost of Solar Technology***		
			Patagonia Sin Represas
			New Auctioning Process
AD			***Env. Regulation Changes***
Wind and AD			*Clean Dev. Mechanism*
Wind, Solar and AD			***Price of Electricity***

Table 4.2: Relative significance of germination period technology-push and demand-pull events for the attractiveness of the entrepreneurial opportunities. *The bold texts indicate the most significant events. The table encapsulates my own judgements about the categorization and relative significance of the events, and is, therefore, subjective. My judgements, however, were based on the objective data presented in Section 4.2.*

One thing to note about these results is that *internal* technology-push factors were not significant in any of the cases: in the one case where technology-push was important, it was an external influence. Given that the main units of analysis in this study are processes of development of *new-to-the-country* infrastructure sectors – which, by definition, depend on technologies pioneered somewhere else – this is perhaps hardly surprising. It is, however, not *inconceivable* for such processes to be driven by internal technology-push factors: this, in fact, is to a large extent what happened with China's Solar infrastructure sector, which has benefited from technical progress in the Solar manufacturing sector as much as any other country, only in this case the progress has largely been domestic (Yip and McKern, 2016). Although it is important to mention that China's Solar manufacturing sector did succeed in 'technology-pushing' its Solar infrastructure sector (because it shows that this 'forward linkage' (Hirschman, 1958) is not unfeasible), it is crucial to note that this country's much larger domestic economy[70] and higher degree of economic complexity[71] – not to mention that it is not an HME (Schneider, 2013) – turns comparisons with Chile somewhat far-fetched. Unless they are part of broader, long-term, and export-oriented industrial development strategies, technology-push policies in Chile could hardly be expected to lead to equivalent results. The economic development opportunities open to countries are not just contingent on their current level of development: they are also dependent on structural characteristics such as their size[72].

The second notable aspect of the results is that, despite the fact that what infrastructure sectors 'produce' is not the easiest to export, and that the three ones under study did not export at all, a few of the demand-pull factors that changed the context through the germination periods were the result of external influences – namely, the Argentinian Gas Crisis and its effect on the price of electricity, and the CDM. Domestic demand for the new kinds of infrastructure was thus not just an outcome of economic growth, but also the result of a fluctuating external environment – one that, as these results show, can influence sectoral emergence processes even if the sectors in question do not produce exportables.

[70] According to www.google.co.uk/publicdata/, its GDP in 2013 was about 33 times large than Chile's.
[71] In 2014, China's 'economic complexity index' was 0.74 (placing it as the 37th most 'economically complex' country), while Chile's was only 0.25 (placing it as the 58th most complex country). For reference, the most economically complex country is this year was Japan, with an ECI of 2.25.
[72] Although China's Solar manufacturing sector has from the outset been export oriented, its early Wind manufacturing sector was largely focused on its domestic market (Yip and McKern, 2016). This shows that it is not unfeasible to conceive of a Chinese Solar manufacturing sector focused on the domestic market. The development of a Chilean Solar manufacturing sector focused on the domestic market, on the other hand, is remotely unlikely.

4.5. Wrapping Up

Our main goal in this chapter was to better understand how, and when, the entrepreneurial opportunities that underpinned the development of the Chilean Wind, Solar and AD sectors originated. We sought to do this by identifying the three innovations that underpinned each sector, and analysing the events that made them more or less attractive opportunities in the years before entrepreneurial agents started to pursue them.

The chapter started by describing the three innovations and briefly recounting their career in Chile by 2016. The milestone that we used to date the process by which these innovations started to diffuse was the year when at least three different sponsors had built at least three different non-pilot facilities. We called this the take-off year. The Wind sector, we saw, took off in the year 2009, and had, by 2016, seen 17 different sponsors complete 22 different projects (Figure 4.1). The Solar sector, which took off in 2014, came later but rose much faster: by 2016, this sector had already seen 22 different sponsors complete 40 different projects (Figure 4.2). The AD sector, finally, came a few years earlier than the last two: taking off in 2006, it had by 2016 seen 33 different sponsors complete 48 different projects (Figure 4.3). In terms of the size of the investments involved, this last sector was however far smaller – orders of magnitude smaller – than the other two. And the AD sector was also far more diverse: while the wind farms and solar PV systems that were built in these years were are all similar energy sector facilities with the unique purpose of generating electricity, anaerobic digesters were much more varied in their design, and they were moreover often multi-purpose: although their main purpose was often waste treatment, the biogas they generate as a by-product was sometimes used to generate thermal energy – or, in later projects, electricity – and, in a few cases, it was burned to generate CDM CERs.

Once we had described these innovations and their career, we undertook to analyse the events that most significantly altered their attractiveness before and shortly after they started to become more common. More specifically, we looked for significant events in the dozen years going from ten years before the take-off years until two years after, a timespan that we called the germination periods. Our analysis showed that, although the price of fossil fuels – an important context variable for all of the cases – was erratic, it generally made thermoelectricity less competitive by the time each sector took off than ten years earlier, making NCRE generation technologies more attractive. The evolution of the price of electricity, another crucial parameter, was also clearly a positive development for all cases, one which was the product of the Argentinian Gas Crisis, regulatory attrition, and the passivity of the established electricity supply-side. The establishment of the Clean

Development Mechanism was significant for the Wind and AD sectors, but its collapse in 2012 made it irrelevant for the Solar sector. And the Renewables Obligation, which should, in theory, have made a significant difference to the Wind and Solar sectors, in practice was important only to this last one. This was because, soon after it came into effect, it came to be largely met with small-hydro and biomass (different from biogas) power plants. A social movement called *Patagonia Sin Represas*, we then saw, had an indirect but profound impact in Chile's energy sector. The effect came on time to significantly drive the take-off of the Solar sector, but was felt in the other sectors only after their germination periods had finished. The evolution of the cost of the underlying technologies was, in turn, a factor that positively affected the Solar sector, negatively affected the Wind sector, and did not affect the AD sector. And the establishment of a new electricity auctioning process was positive for both the Wind and Solar sectors, but took place within the corresponding germination period only in the last case. Finally, the tightening of environmental regulations that started to happen in the second half of the 1990s was a significant positive development for the AD sector.

After going through these various events, we took a step back and made an effort to look at their overall effect for each of the cases. In the case of Wind, we saw that the most significant germination period event was the rise in the price of electricity, and the second most important the increase in the cost of the underlying technologies. The other two events relevant to this case were comparatively less significant. And then we concluded that, even though there was some evidence that building wind farms to generate energy was not an altogether unattractive entrepreneurial opportunity at the beginning of this sector's germination period, it was a much more attractive one by its end. In the case of Solar, we saw that, by far, the most significant event was the decrease in the cost of the underlying technologies, although the three other relevant events also had a very significant positive effect. The conclusion, in this case, was that generating electricity using solar PV systems was an enormously more attractive opportunity by the end of this sector's germination period compared to what it had been at its beginning, when there is good reason to believe it was altogether unattractive. In the case of AD, we saw that the regulatory tightening of Chile's environmental standards was the most significant development, followed by the institution of the CDM and then by the rise in the price of electricity, this last an improvement in the context that came to be relevant only to a later generation of facilities. As with wind farms and solar PV systems, we concluded that the building of anaerobic digesters was a more attractive opportunity by the end of this sector's germination period compared to what it had been at its beginning. However, it was in this case difficult to convey an approximate idea of the magnitude of the change, or to know whether building anaerobic digesters before the AD germination period started was just not as attractive as it was when this period ended, or altogether unattractive.

In the last part of the chapter, we contrasted these various events in terms of the internal developments/external influences and technology-push/demand-pull distinctions. In the case of the first of these distinctions, we concluded that the improvement of the entrepreneurial opportunities of the Wind sector was somewhat more driven by external influences; that the improvement of those of the Solar sector was substantially more driven by external influences; and that the improvement of those of the AD sector was somewhat more driven by internal developments. In the case of the second distinction, we concluded that Wind and AD sector opportunities mainly improved because of demand-pull factors, while Solar opportunities improved because of demand-pull and technology-push factors, these last being the most relevant in this case. We finished this part by reflecting on why internal technology-push factors were wholly absent, and on why external demand-pull factors had some significance even though the sectors under study did not trade the infrastructure services they produced. In the first case, we concluded that this was not surprising but also not pre-determined, as exemplified by China. And in the second, we found that external influences could drive the demand for new kinds of infrastructure even though infrastructure services are not easily tradable.

With this, we close the chapter on entrepreneurial opportunities. Our goal for the next chapter is to understand how and by whom these opportunities were pursued.

Section / Concept	Operational Assumption (OA) / Operational Definitions (OD)	Methods (M) / Data (D)
General	- **OA:** A new sectoral development process 'takes-off' on the year when at least three different sponsors have invested in non-pilot facilities. - **OA:** Events that take place before a sector takes off may make its underpinning entrepreneurial opportunities more or less attractive.	- **D:** Scoping interviews. - **D:** Self-compiled projects database. - **D:** Tabulated numerical data (prices, etc.) from various sources. - **D:** Secondary documents from the government, international organisations, etc.
– *Take-off year*	- **OD:** The first year when at least three different non-pilot facilities have been sponsored by different investors.	- **M:** Take-off year calculated from self-compiled projects database.
– *Germination period*	- **OD:** The period that goes from ten years before the take-off year until two years after.	- **M:** Germination period calculated from self-compiled projects database.
Section 4.1.	- **OA:** The self-compiled list of projects includes all Wind, Solar and AD projects that have been built in the country.	- **D:** Scoping interviews. - **D:** Self-compiled projects database.
Section 4.2.	- **OA:** Germination period events that interviewees identified as having significantly increased or decreased the allure of the respective entrepreneurial opportunities provide a sufficiently rich basis for further inquiry based on a revision of secondary data and documentation.	- **D:** Scoping interviews. - **D:** Tabulated numerical data. - **D:** Secondary documents. - **M:** Further qualitative (and when possible quantitative) inquiry about all events listed by interviewees and derived or related events.
Section 4.3.	- **OA:** It is possible to make sound tentative judgements about the relative significance of the various events for the different opportunities by weighing and comparing the evidence from secondary data and documentation.	- **M:** Weighing of the available evidence base.
Section 4.4.	- **OA:** It is possible to make sound tentative judgements about the relative significance of the various events for the different opportunities by weighing and comparing the evidence from secondary data and documentation.	- **M:** Weighing of the available evidence base.

Table 4.3: Summary of data, methods and operational assumptions/definitions used in Chapter 4

Chapter 5

The Entrepreneurial Function

What influenced the kinds of economic agent that contributed to the entrepreneurial function, and the nature of their contribution, in the Chilean Wind, Solar and AD sectors?

Pursuing the entrepreneurial opportunities that were shaped by the events described in the previous chapter involved a) discovering contexts and locations where the infrastructure facilities could bring net gains, and developing specific projects for these, and then b) sponsoring and financing (building) those projects. Different kinds of economic agents contributed to these two parts of the entrepreneurial function in infrastructure sectors, and the nature of their contribution was not always the same. In this chapter, we will inquire about whom these were, how they contributed, and why.

The chapter is divided into four sections. In the first, we will characterise the broader sectors which the case studies are part of, this according to a number of dimensions which, as we saw in Chapter 3, are often deemed relevant to the nature of entrepreneurial activity. In the second, we will go through a detailed account of the contribution that different kinds of economic agent made to the entrepreneurial function in the emergent sectors. In the third, we will further discuss the most salient features of these results. And in the fourth and final, we will wrap up the chapter.

5.1. The Broader Sectors and their Established Order

As we have seen, the Wind and Solar sectors were both part of the broader Electricity Generation sector. And, although the AD sector was also, to some extent, part of it, it was to a larger extent part of the Waste and Wastewater Treatment sector. Therefore, the three processes of emergence of new sectors that we are studying were part of the process of transformation of the EG and the WWT sectors. Understanding the prevailing order in the EG and WWT sectors as the cases developed is crucial to understanding the development trajectory that they followed (Malerba and Orsenigo, 1996).

Among the many features of the established order that we could in principle look at, four are the most relevant for our purposes. The first of these is the global context, i.e. the state of affairs in the sector at the worldwide level; this is relevant because, as we've seen, the global features of a sector are often important determinants of its local manifestations (Gereffi et al., 2005). The second is the origin and identity of the respective incumbents at the local level; as we've seen, much of the most interesting research about sectoral transformation processes revolves around the reasons why it is sometimes these that bring change about, while, on other occasions, it is new entrants (Breschi et al., 2000; Christensen, 1997); if we are to engage in this discussion, we must identify and describe these local incumbents. The third is the technological regime: the technological opportunities, appropriability conditions, cumulativeness conditions, and knowledge base that prevailed in the EG and WWT sectors as the sectors under study were emerging within them; these features of the established order, recall, have been shown to be significant determinants of whether the most innovative agents will be the incumbents or new entrants (Breschi et al., 2000; Breschi and Malerba, 1997), and are thus very relevant to our discussion. And the fourth and final is the nature of demand, which research that we have previously reviewed often has shown to be a crucial shaper of entrepreneurial activity (Christensen, 1997; Malerba et al., 2007; Malerba and Nelson, 2011).

5.1.1. The Electricity Generation Sector

The years covered by this study were a period when the EG sector was dawning on a profound and worldwide transformation toward more sustainable ways of using and producing this key economic resource (Verbong and Geels, 2010). On the consumption side, all sorts of energy efficiency innovations, both technological and organisational, were being developed and deployed at all levels: households, industries, countries, etc. And on the supply side, the main development was the rapid rise of NCRE generation technologies, particularly wind and solar (Kost et al., 2013). Although the aggregate capacity of these new forms of generation was still an order of magnitude smaller than that of conventional energy generation sources, they were growing fast, and were threatening the long reign of the incumbent technologies.

The Global Context

The global EG sector was dominated by two kinds of firm: the technology providers and the utilities. The first of these were what Pavitt would call *specialised supplier* – and in some cases *science based* – firms: firms with strong technological capabilities whose competitiveness was highly dependent on their innovations and their ability to appropriate the rewards coming from them (Pavitt, 1984). The most significant among these firms were probably General Electric and Siemens. Although both of these were among the top ten providers of wind technologies[73], neither was a significant solar technology provider: solar technology provision was less concentrated, and dominated by newer firms such as First Solar, Yingli, and Trina Solar[74].

The second kind of firm, the utilities, were what Pavitt would call *supplier dominated* firms (Ibid.): firms with relatively basic technological capabilities[75] whose competitive edge came not from their in-house technological innovations, but rather from their ability to adopt new and better third-party technologies faster than their competitors, and from their ability to cut costs and improve their services through organisational and commercial innovations. Some of these utilities were huge multinationals that owned and operated facilities throughout the world. But there were also a myriad of smaller utilities, many of them not international. A number of firms, particularly in the Solar sector, were both technology providers and utilities, but this was more the exception than the rule.

The utilities were the customers representing the demand side for technology providers, and the market that joined the two was probably closest to what Gereffi et al. (2005) called a *modular* value chain. In this market, explicit coordination and power asymmetries among the parties were not so high. However, the fact that the technology suppliers provided expensive capital goods, often tied to insurance and service contracts, meant the costs of switching from one provider to another were not as insignificant as they are in fully commoditized markets such as those of wheat or metals.

The Local Incumbents

In Chile, the EG sector was solely composed of utilities: all of the technology providers were foreign. The first of the country's utilities was Endesa, a state-owned firm created in 1944 by CORFO, the government's main economic development promotion organisation. In its first four decades of existence, Endesa had a monopoly in the Chilean

---

73 www.energydigital.com/top10/3705/Top-10-Wind-Turbine-Suppliers

74 www.renewableenergyworld.com/ugc/blogs/2010/06/top-10-ten-largest-solar-pv-companies.html

75 It is important to clarify the sense in which the term 'basic technological capabilities' is used above, for while EG utilities typically were supplier-dominated, often they did have to face significant engineering challenges that required capabilities which were not easy to master (challenges which were typically associated with operating and coordinating with the electricity grid). In terms of Bell's taxonomy of capabilities, the above means that while the utilities of the EG sector may often have had strong 'production' and 'design & engineering capabilities', their rarely had strong 'R&D capabilities' (Bell, 2007). Or, in terms of Amsden's taxonomy, while these utilities may often have had strong 'production' and 'project execution' capabilities, they rarely had strong 'innovation' capabilities (Amsden, 2001).

Electricity Generation, Transmission, and Distribution sectors, owning and operating the vast majority of the facilities of the country's electricity system (Ortega, 1989).

This state of things remained until the Pinochet dictatorship, which in 1982 initiated a full re-design of the electricity system, one that followed the deregulation scheme described in (Joskow and Schmalensee, 1983). Before he was ousted in 1989, the dictator and his aides passed regulation that effectively opened the EG sector to private sector participation, and dismembered Endesa into more than a dozen smaller firms which were then privatised, maintaining the name Endesa for the largest of these. As the sector opened, the now shrunk and privatised Endesa, and its various siblings, were gradually joined by a number of other firms, both national and international. The ownership of many of these firms was traded in the stock market, and the control of the new utilities regularly changed hands. As a result, many of the country's electricity sector firms and assets – including Endesa, still the largest of the country's utilities – came, by the 2000s, to be controlled by foreign capitals (Sohr, 2012).

The utilities relied on a wide and diverse network of engineering and other kinds of specialised services firms to support their activities. Most of these, too, were originally domestic firms. However, as the worldwide trend of increasing concentration and internationalisation of engineering services firms advanced (Miozzo and Soete, 2001), several of the largest of them also came to be controlled by foreign capitals, and many new international ones arrived.

The Technological Regime

Being supplier-dominated firms (Pavitt, 1984), the utilities and their support network innovated by adopting new technologies and using these to build better power plants. The technological regime – the technological opportunities, appropriability conditions, cumulativeness conditions, and knowledge base (Breschi et al., 2000; Malerba and Orsenigo, 1993) – that shaped this kind of innovation was related, but different, from that which shaped the innovative behavior of the technology providers, whom innovated not by adopting new technologies but rather by creating them. The regime of the utilities, and not the one of the technology providers, was the one that most directly affected the process of emergence of the Chilean Wind and Solar sectors, and it is it, therefore, that is relevant for our analysis.

Arguably, on the years under study, the technological opportunities of the regime of the EG utilities were on the rise. The rise was driven by the progress that technology providers were making in various areas, and particularly in wind and solar technologies (Kost et al., 2013). As we saw in the previous chapter, such progress had a notable effect on the price of solar PV system components; and although, in the case of wind, the cost decrease that technical progress should have brought was overcome by supply shortages which had the opposite effect, it was nevertheless present. How high or low these opportunities were depends on what one is comparing them with. If we make the comparison with, say, the computer industry in its early years, then these were probably low (Malerba et al., 1999). But comparing the technological opportunities that prevail in an infrastructure sector with those that prevail in a manufacturing sector is of little relevance. More apt comparisons are those which one can make with the recent past of the same sector and with other infrastructure sectors. Thinking in terms of the first of these comparisons, the technological opportunities that prevailed for the utilities of the EG sector were arguably high compared to what they had been twenty or thirty years before the Wind and Solar sectors took off in Chile: back in those days, the main EG technologies – hydroelectricity, thermoelectricity, and nuclear power – were well established, and there were not – as there would later be – so many promising alternative generation technologies for utilities to consider adopting. Thinking in terms of the second comparison, it is unclear whether the opportunities were high relative to other infrastructure sectors: although there are several infrastructure sectors (e.g. irrigation systems and highway systems) that were not at the time being disrupted by new technologies, there were many (e.g. public city transport systems) that were.

Moving on, the appropriability conditions of the regime of these utilities probably varied depending on the EG technology, but seemed relatively low for turn-key power plant technologies such as wind and solar[76]. If a utility innovated by successfully adopting a new technology – e.g. by building wind farms to add to their generation assets portfolio – there was little they could do to prevent other utilities from imitating them. They could obviously not, for a start, patent the idea of building wind farms, which is the appropriability device commonly used in, say, the drugs and biotech sectors. And they could also not prevent imitation through secrecy, the device commonly employed in the chemicals sector (Levin et al., 1987).

In the case of the cumulativeness conditions, these did give the incumbent utilities some advantage over potential new entrants. Compared to a potential new entrant, an

[76] The situation of nuclear power plants is wholly different: here both the appropriability and cumulativeness conditions are considerable. These are also probably higher in the case of some conventional electricity generation technologies, in particular large hydroelectricity.

incumbent utility which had never built a wind farm or a solar PV system before, but which owned and operated other energy assets and was active in the energy commercialization business, already had capabilities which the potential new entrant did not have, but would need to develop in order to enter the Chilean energy commercialization business. These capabilities related to activities such as the proper integration of its power plants to the grid, and the negotiation of good energy commercialization terms – non-trivial activities which required significant country-specific knowledge about the transmission network, the modus operandi of the network operator, and the design of the electricity market, among other things. Thus, the accumulated experience of the incumbents did give them a not inconsiderable advantage over potential new entrants. However, when one puts these advantages in perspective by comparing them with those of incumbents in other sectors, these do not seem as large. In engine manufacturing, for example, the accumulation of technical knowledge arguably gives incumbents a far greater advantage over potential new entrants, for the technical challenges that need to be tackled to build new turn-key infrastructure facilities[77] such as wind farms and solar PV systems are far smaller than those that need to be tackled to create new engines. Similarly, the cumulativeness conditions of most chemicals sectors arguably give their incumbents far more significant advantages than they gave to the incumbents of the Chilean EG sector.

Finally, the nature of the knowledge base of the EG utilities was fully in the camp of the applied sciences, except perhaps with nuclear energy power plants: building all other kinds of power plants was a conventional engineering challenge, and not an undertaking that required mastering the basic sciences. The basic sciences were often relevant to the technology providers, but not so much to the utilities and their support network.

The Nature of Demand

In Chile, the character of the demand for electricity generation services (for brevity, generation services, which is what the EG sector provides) was largely determined by the complex body of regulations that, as we've seen, started to be put in place from 1982[78]. Some of the basic features of the demand for these services that the regulation shaped were already described in the previous chapter (call/option PPA contracts, SPOT market, lowest-

---

[77] To be sure, things are different for non-turn-key facilities such as large hydroelectric and nuclear power plants.

[78] The description in this chapter refers to the rules that were in place after substantial reforms that took place in 2004 and 2005. Among many other things, before these reforms, distribution utilities were not obliged by law to sign PPA contracts with generation utilities.

variable-cost-comes-first rule, etc. – see Section 4.2.7). We now complement the account by describing some further features of its nature.

In Chile, there were two main sources of demand for generation services: demand from large energy consumers, and demand from smaller residential and commercial consumers. The demand from smaller residential and commercial consumers, however, was mediated by the distributors. To the eyes of the generators, this made these distributors large energy consumers in their own respect – indeed, the largest of all. But the law distinguished among the two kinds of consumer.

Large energy consumers – such as mining firms, manufacturing facilities, large commercial buildings, and the likes – were free to negotiate PPA contracts with any generator that they wished. The generators, however, were obliged to follow the operational instructions of the network operator. This, as we've seen, meant the when their contracts required them to provide energy, but the operation rules said their facilities should be offline, they were obliged to honour their contracts by buying energy from the SPOT market. The contracts among these large energy consumers and the generators were private, and the two parties were largely free to decide on their content.

Smaller residential and commercial consumers, on the other hand, were not allowed to negotiate directly with the generators: they had to buy their energy from the distributors. Distribution being a natural monopoly, these last operated regulated concession areas. Importantly, consumers were not allowed to choose their distributors: while some liberalized electricity systems, such as the UK's, distinguish among electricity distribution and retail, and enable consumers to choose their retailers (which may out-compete each other by offering them different pricing structures, different mixes of green vs. non-green energy, and so on), the Chilean distributors were also the retailers. However, the prices that these distributors charged were not determined by them: they were calculated based on the price they had to pay to the generators for the electricity they bought from them, and on the regulator's estimate of the operational costs of distribution. Crucially, the distributors did not decide which generators to buy their electricity from, nor which price to pay them: decisions on both of these matters were an outcome of the regular electricity auctioning processes conducted by the regulator, processes that followed pre-agreed rules known to all parties, and that strictly favored generators offering the lowest prices.

The essential features of the demand for generation services that this system created were two: its complexity and its openness. Demand for electricity services was highly *complex* because generators could not just turn their power plants on and expect to get a certain income per kWh of generated electricity. On the contrary, generators a) could not decide when to turn their power plants on, and b) could not know in advance how much they would be paid for the electricity services they provided[79]. Due to these complexities, some of the most challenging aspects of the business of providing electricity services were to estimate the long-term incomes of projects and to structure their commercial aspects – both things which greatly benefited from deep knowledge of the relevant regulations and the operational realities of the system, and from the ability to forecast its medium to long-term development trajectory. Finally, demand for electricity services was *open* because, a) since the operators of transmission lines were not allowed to deny generators the interconnection of their facilities to their transmission lines, and b) since any generator could freely negotiate contracts with large energy consumers and participate in electricity auctions to provide the distributors, then c) in principle[80], any economic agent, operating from any location, could offer these services to the open market in return for an income (MINENERGIA/GIZ, 2009).

5.1.2. The Waste and Wastewater Treatment Sector

In the years when the Chilean AD sector was taking off, growing environmental pressures from urbanisation and various other economic development processes were bringing change to the global Waste and Wastewater Treatment sector. Slowly, but surely, the sector was moving from conceiving waste as a passive to be discarded to a resource to be managed, and the new maxims were to reduce, reuse and recycle. In general, the move was more driven by the passing of new and more stringent environmental regulations than by breakthroughs in technology, as many of the technologies that were being used had long been available and mature (UNEP/ISWA, 2015).

The WWT sector was in several respects more diverse than the EG sector, this in large part because of the broad range of waste that the sector treated: solid garbage from cities, effluents from industrial processes, blackwater from households, agricultural waste, etc. Often, several different schemes could be used to treat each of these kinds of waste, schemes whose success depended at least as much on the design of a well-adapted logistics plan than on the use of one or another waste treatment technology.

[79] The system was in fact substantially more complex than the simplified account given here. For example, in addition to payments for MWh of generated electricity, generators also received payments, in a separate 'capacity' market, for MW of power that they made available to the system. However, the simplified account provided here and in the previous chapter is enough for our purposes.

[80] In practice, no doubt, there were technical and economic barriers of entry (see CHILE SUSTENTABLE, 2011), but the design of the system was such that it tried to minimize them.

The Global Context

As a result of its diversity, the economic agents that prevailed in the WWT sector at the global level were also very varied. In some cases, e.g. effluents from industrial processes and agricultural residues, waste – when it was not just dumped untreated – was often treated by its generator. But in many others, e.g. solid garbage from cities and blackwater from households, waste was usually collected and treated by public and in some cases private utilities. A few of these utilities, e.g. Veolia Environment, Suez Environment, and ITT Corporation, were large MNEs active in many countries.

Like those of the EG sector, the utilities of the WWT sector were for the most part *supplier dominated firms*: firms which may often have had considerable production and design and engineering capabilities, but which rarely had strong R&D capabilities (Bell, 2007; Pavitt, 1984). The technology providers of these utilities (the 'suppliers' that 'dominated' them) were as diverse as the different waste treatment needs, ranging from firms making specialised trucks to collect residential waste, to firms dedicated to the improvement or design of new biological or chemical waste treatment processes. Often, WWT utilities offered integral waste treatment solutions requiring the use of several complementary technologies, as well as the design of complex logistic schemes and civil works.

In many cases, the market that joined the WWT technology providers with its clients (when they were not one and the same, which did sometimes happen) was one based more on the transaction of services than on the transaction of goods: often, what the technology providers of the WWT sector had to offer was their knowledge about how to provide an appropriate waste treatment solution to their customers, solutions which would often require standardized and widely available materials (e.g. standard chemicals) and capital goods (e.g. pumps, valves, trucks, shredders, etc.). Thus, rather than manufacturing firms, WWT sector technology providers were often consultancies that traded in tasks (Lanz et al., 2011).

The Local Incumbents

Like in many other parts of the world, WWT services in Chile were, until some decades ago, chiefly provided by public utilities. However, as happened with the EG sector, with the advent of the military dictatorship and its Chicago-influenced economic program a substantial share of the provision of these services was privatised. This was especially the case with water treatment services: in this sub-sector, 95% of people was by 2014 served by private utilities. Many of these utilities had originally been public, and many were by then controlled by large MNEs such as Agbar-Suez (Romeu, 2014).

In the case of urban solid residues, the system was more mixed. Municipalities had been traditionally in charge of household waste collection, and they still played a major role in this area, either by organising and running the service or by overseeing third parties that did it for them. The waste that was collected was, for the most part, dumped untreated to landfills or illegal dumps, many of which were owned and operated by private firms which charged a fee per tonne of waste thrown to the facility. More dangerous kinds of urban waste, e.g. residues from hospitals, were collected and disposed of by private companies that charged a fee for the service. Some municipalities had modest recycling systems, often run by an informal network of recyclers.

When they were treated, industrial and agricultural residues were normally treated by their producers within the facilities where they were generated. In this, the owners of the facilities were supported by a sizable sector of environmental and engineering services consultancies that also often worked together with the large utilities to provide waste treatment solutions.

The Technological Regime

The diversity of waste treatment needs and solutions meant there was not just one technological regime that affected innovative activity in the WWT sector: in terms of technology, handling solid waste by dumping it into a modern landfill is wholly different from incinerating it in a state-of-the-art incineration plant, and these two solutions are in turn wholly different from the kind needed to treat liquid waste through chemical or biological processes. What is most relevant to the case of the AD sector, however, is the regime that applied to biological and chemical waste treatment solutions, and it is, therefore, this regime that we will focus on. Again, we do this from the point of view of the WWT utility or solution provider rather than from that of the technology provider.

The technological opportunities relevant to this part of the WWT sector were, as with the EG sector, arguably on the rise. The biological sciences were one of the most active science areas in the last part of the XX and the beginning of the XXI centuries, and there were many waste treatment problems that these were well suited to tackle. Together with complementary advances in instrumentation and chemicals, advances in the biological sciences were easing the development of many new waste, and particularly wastewater, treatment technologies: a 2013 survey by the US Environmental Protection Agency lists 64 such technologies, some emergent and some that had already been tried at scale; these included the likes of the '*Magnetite Ballasted Activated Sludge'* process, the '*Microbial Fuel Cel*' process, and the '*Vacuum Rotation Membrane (VRM®) System*' (EPA, 2013). Thus, a waste treatment solution provider had ample room to innovate by adopting some of these (or other) newly emergent technologies and adapting them to their solutions – if they themselves were not developing the technologies in the first place, which did sometimes happen.

From the point of view of the biological or chemical WWT solution providers, the appropriability conditions were however not very high. The reasons were much the same than for the EG utilities: if a solution provider successfully innovated by adopting a new WWT technology, there was little it could do to prevent followers from imitating it. However, the solution providers, occasionally, used self-developed the technologies. When this was the case and technology provision was integrated with solution provision, the appropriability conditions were more substantial, because waste treatment processes could be patented.

The cumulativeness conditions of these WWT solution providers were, on the other hand, significant. WWT solutions based on biological or chemical processes were usually *not* turn-key facilities to be bought from the shelf. More often, they required substantial tweaking of parameters and other sorts of adaptations to local conditions in order to be successful, and these adaptations required significant degrees of tacit knowledge that could only be acquired through experience. Moreover, these solutions were often organised in families of related schemes, meaning that if a provider mastered one of them, it would in the process learn about the whole family and could in the future provide derived solutions. In addition, biological or chemical WWT solutions were often flexible ones that could be adapted to different needs – as long as the solution provider had accumulated the knowledge that this would require.

From the point of view of the providers, the nature of the solutions' knowledge base was not clearly within the applied or the basic sciences, but rather had some of both. Many solutions relied on known biological or chemical processes, but mastering the scientific basis of those processes, and understanding how to apply this knowledge to tweak them, would often be crucial to implementing well-adapted solutions based on them. Such knowledge was both scientific and applied.

The Nature of Demand

One of the main features of the potential demand for waste and wastewater treatment services was its *diversity*. Many different activities, as we've seen, generate many different kinds of waste, and the variety of potential waste treatment needs is correspondingly broad. Nevertheless, this demand may be roughly organised in residential, industrial, and agricultural.

In Chile, residential waste treatment needs were limited to household wastewater treatment, for household garbage was seldom treated: normally, it was just collected (waste collection was in charge of municipalities, which usually hired private firms to operate the service) and dumped in landfills (which were also often operated by private firms, though some were operated by municipalities). Like electricity distribution, the treatment of wastewater was a natural monopoly and was therefore organised around a system of regulated territorial concessions. These wastewater utilities were normally awarded contracts that did not just require them to treat wastewater, but also to collect it and to treat drinking water for city consumption. Therefore, wastewater utilities were normally broader, integrated water management utilities (Romeu, 2014).

Industrial waste treatment needs were different from residential needs in that these were not in charge of utilities. Instead, it was the waste generators themselves whom were required by law to treat waste to a certain minimum standard before disposing of it in authorised venues. The venues were often the same ones where household waste ended up: sewer networks and landfills, though in some specific cases, such as with dangerous biological residues from hospitals, waste was incinerated. The range of industrial waste was broad and, in Chile, encompassed many kinds of organic residues that could be treated using anaerobic digesters, including waste from large-scale livestock producers (chiefly swine and poultry producers), slaughterhouses, breweries, distilleries, fruit and vegetable processors, dairy producers, and winemakers, among others (Chamy, 2007).

Potential demand for waste treatment services from the agricultural sector, finally, came from both farming and animal husbandry. Farming residues (husks, roots, pruning residues, etc.) could in principle be anaerobically digested. However, this made economic sense only if it was for energy generation, for there was otherwise little incentive to treat these residues, which, moreover, often had alternative uses. Manure from animal husbandry, on the other hand, could become a waste treatment issue for which anaerobic digesters could provide a solution. This was particularly so for cattle producers, for a large share of the other two main kinds of livestock production activities – swine and poultry production – was undertaken on an industrial scale. Besides waste treatment and energy generation, the solution, in this case, could potentially be valuable in a third way: by generating fertiliser for the crops (Chamy, 2007).

The second key aspect of the demand for waste and waste treatment services was the fact that regulatory requirements, and logistic and transportation costs, often made it unviable to provide the service from locations which were not within close range of the waste generating activities. As we saw, with the regulatory tightening of environmental standards that started to take place from 1994 (see Chapter 4, Section 4.2.8), liquid industrial residues could not be discharged into waterways or sewerage systems before they met certain standards, even if this wastewater was to be further cleaned downstream in the industrial wastewater treatment plants that also treated household's wastewater. And, given that the public sewerage system was often unavailable to raw industrial waste, logistic and transportation costs would often make it uneconomical to transport these residues to centralised waste treatment locations, so as to pool waste from different industries and treat it taking advantage of economies of scale. Similarly, agricultural residues were often dispersed and costly to transport, making it unviable to treat these too far from where they were generated. Household wastewater was the only exception, for sewerage systems did transport this to centralised waste treatment facilities run by the water utilities. But even in this case, the location of these facilities was largely determined by transportation and logistics considerations. Thus, in contrast with demand for electricity generation services – which could be provided from, in principle, anywhere within the territory – demand for waste treatment services was far more *localised* (Chamy, 2007; Romeu, 2014).

5.2. The New Sectors, the Various Agents, and their Different Contributions

Having characterised the broader sectors that the Chilean Wind, Solar and AD infrastructure sectors were part of, our next task is to find out and discuss the contributions that different kinds of agents made to the respective entrepreneurial functions. In large part, we will do this by analysing in depth the self-compiled projects database, whose sources and compilation methodology was detailed in Chapter 3. But before we do this, we need to gain a proper understanding of how the two most important parties to infrastructure projects – the project developer and the project sponsor – tended to relate to each other in each of the sectors, for, as we'll see below, this will be crucial to understanding the nature of the entrepreneurial contribution that different kinds of agents made.

5.2.1. The Transition from the Development to the Investment Stage

As we saw in Chapter 3, bringing infrastructure facilities into operation normally involves going through a development stage (planning, studies, design, permits, etc.) and then an investment stage (procurement, construction, operation, commercialization, etc.) (Khatib, 2003, pp. 22–28). And the transition from one stage to the other may be analysed as a transaction taking place among the project developer and the project sponsor (Williamson, 1981, 1979). This transaction, recall, may be organised around three different modes of governance.

The transaction, first of all, may take place in the marketplace. In other words, the project – which, while in the development stage, is still a 'paper' project – can be treated as a 'good' and sold to a sponsor by an economic agent who has developed it independently, i.e. without previously having signed a contract with the buying sponsor. In Williamson's terminology, this is called *market governance*, but we may also call it *independent development*.

Second, the transaction may take place between a developer and a sponsor who have signed a contract before the development of the project has started or very early on within the development stage. In this case, the developer acts as a service provider or consultant to the sponsor, and does not need to worry about finding a buyer for the 'paper' project once it is ready to be sold, as the buyer – the sponsor – is there and has committed to pay from the outset. Williamson calls this *contractual governance*, but we may simply call it *consultancy*.

Finally, the transaction can take place within one and the same organisation. In this case, the developer and the sponsor are the same: instead of outsourcing it to a third party, the sponsor develops its own projects. Williamson calls this *unitary governance*, but we may also call it *self-development*.

Figure 5.1 shows the prevalence of each of these three distinct kinds of relation among the developers and sponsors of Chilean Wind, Solar and AD projects. The figure was built from data about completed projects only, for projects still under development or shelved have not, by definition, yet been sponsored by anyone. One can see there that, until 2016, most wind and solar projects were either developed independently (i.e. with the purpose of selling them to an external sponsor), or self-developed by the sponsor itself. By contrast, AD projects were generally developed by consultants which entered a contractual relation with sponsors before they engaged in their project development activities.

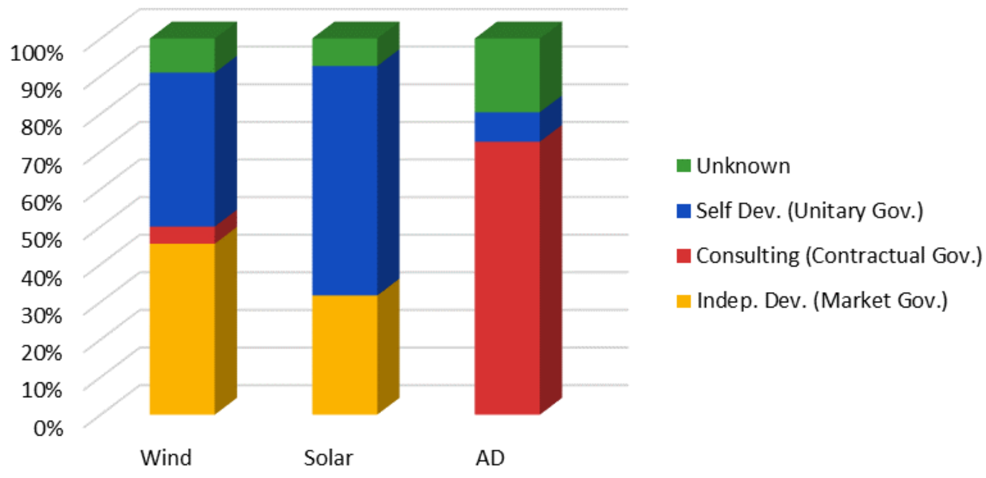

***Figure 5.1: The relation among project developers and sponsors.** Firms developing projects independently to sell them to third-party sponsors were common in the Wind and Solar sectors, but not in the AD sector. Most developers in this last sector were consultancies. Source: own elaboration based on self-compiled projects database.*

Hence, the different ways in which they related to sponsors made the nature of the contribution to the entrepreneurial function by Wind and Solar sector developers rather different from that by AD sector developers. But was the significance of these differences? The key to this question lies in the different risk profile that project development activity entails under the various modes of governance. From a broad perspective, the main risk of the development stage of a project is that of investing resources in the planning and design of a facility that may never be completed, either because techno-economic studies show it to be unviable, permits cannot be acquired, finance cannot be secured, or any other reason. The main risk of the investment stage, on the other hand, is that of investing resources in the construction and operation of a facility that does not bring back the expected benefits. Although the investment stage risk is, by definition, always assumed by the sponsor, the development stage risk may a) be fully borne by the sponsor, which is what happens when this last is a self-developer; b) be shared among the developer and the sponsor, which is what happens when the developer acts as a consultant to the sponsor; or c) be fully borne by the developer, which is what happens when this last acts as an independent developer. As we've seen, one of the defining traits of an 'entrepreneurial orientation' is to take risks (Lumpkin and Dess, 1996). Thus, in one important sense, independent developers – whom did not know whether they would get a return on their development stage investments – were more entrepreneurially oriented than consultants. These last could be more confident that they would get such a return because would have signed a contract with a sponsor before they undertook to develop a project[81]. As a consequence, all other things being equal, independent developers, because they took bigger risks, made a more significant contribution to the entrepreneurial function than consultant developers. When, as in the AD sector, it was consultants that dominated, the contribution to the function of sponsors was doubly significant, for in addition to the investment stage risk, these had to bear much of the development stage risk.

5.2.2. Classifying the Agents

The next step in our analysis is to discuss the extent to which different kinds of developers and sponsors contributed to the two key parts of the entrepreneurial function. More specifically, we want to understand the extents to which a) incumbent vs. new entrant, and b) domestic vs. foreign entrepreneurial agents contributed to project development and project sponsorship, this for reasons that we already went through in Chapter 3. However, in order to get an image of what happened that is not severely distorted by the use of categories that are too coarse, we will, in both cases, need to add an in-between category where we classify the many developers and sponsors that were not clearly domestic or foreign, or were not clearly incumbent or new entrants. In consequence, we will divide these entrepreneurial agents into the nine categories of Table 5.1. In this table, the left-right axis corresponds with the incumbent - new entrant distinction, and the top-down axis with the domestic - foreign distinction.

	Incumbents	**Diversifiers**	**New Entrants**
Domestic	Domestic Incumbents	Domestic Diversifiers	New Domestic Firms
Semi-Domestic	Domestic Under Foreign Control (DUFC) Incumbents	Domestic Under Foreign Control (DUFC) Diversifiers	Domestic-Foreign Joint Ventures
Foreign	Foreign Incumbents	Foreign Diversifiers	New Subsidiaries

Table 5.1: A taxonomy of entrepreneurial agents based on the incumbent / new entrant and domestic / foreign distinctions.

The *incumbents*, as we've seen, are those economic agents who were active in the Chilean EG or WWT sectors before they became active Wind, Solar or AD developers or

[81] In the case of self-developed projects, it doesn't make sense to weigh the balance of risks, as the developer and the sponsor are the same

sponsors[82]. These are divided in the *domestic incumbents*, which are incumbents of domestic origin and controlled by domestic interests; the *DUFC incumbents*, which are those of domestic origin but which were controlled by foreign interests in the period of study[83]; and the *foreign incumbents*, which are those that were fully foreign subsidiaries of MNEs.

The *diversifiers*, moving on, are economic agents who, though active in Chile before the respective sectors took off, were not active in the broader (EG or WWT) sectors within which these developed; these are in-between the incumbents and the new entrants because, although they are new to the broader sectors, they are not new to the economy. With respect to the domestic/foreign distinction, the diversifiers are divided in the same way as the incumbents, i.e. in the *domestic diversifiers*, the *DUFC diversifiers*, and the *foreign diversifiers*.

The *new entrants*, finally, are the economic agents who constituted themselves in the economy as the sectors under study were developing. With respect to the second distinction, these are likewise divided between the *new domestic firms*, i.e. domestic startups and the likes; the *domestic-foreign (DF) joint ventures*, i.e. joint ventures among a domestic and a foreign economic agent; and the *new subsidiaries,* i.e. the new MNE subsidiaries that arrived as the respective sectors were taking off.

5.2.3. Discovering and Developing the Opportunities

Most Chilean Wind, Solar, and AD project developers were private firms, although in a few AD projects universities acted as developers. Given the project-based nature of these sectors (Bakker, 2010), most of these firms were what Sydow et al. (2004) call project-based organisations (PBOs), i.e. firms engaged in the production of unique and highly customised products or services. In the case of Wind and Solar, some of these firms were multi-project ventures staffed by tens, or, in rare cases, hundredths of employees engaged in the systematic and simultaneous development (and sometimes also the sponsorship) of many projects. Many firms, however, were single-project, i.e. organisations put together to develop a specific project or a small set of related ones. These last were often staffed by less than three full-time workers, whom would outsource many tasks to third party engineering, legal, and environmental service providers. In the case of AD, developers, as we saw, were typically consultancies, often small ones but still multi-project.

[82] To clarify: the incumbents of the EG sector are incumbents to Wind and Solar, and those of the WWT sector are incumbents to AD.

[83] Which, as we saw, happens to be the case with many Chilean utilities and other kinds of firm.

Discovery and Development in the Wind Sector

The discovery of locations with appropriate climatic, economic, regulatory, environmental, and social conditions to build wind farms – all factors relevant to their success – was at times something that *happened to* a lucky but aware landlord, which, having somehow gained awareness that wind farms were becoming more common and good business, reasoned her windy plot of real estate could host one. But, more often, it was the outcome of project developers' systematic scouting of the Chilean territory in search for places that met the criteria for a good location. In this, the early developers had it much harder than the ones that came later, for, as time went by, territorial information became much easier to acquire: if a certain site had good conditions, it was reasonable to think that nearby locations would also have good conditions, and no developer could keep this information to itself for long; and, as the years passed, systematic wind maps that covered the whole territory at reasonably good resolution levels became available, first as the asset of certain firms that built them or hired someone to build them from satellite and other data[84], and then as a public good freely provided by a partnership between the government and a university[85] as a way to foster the development of the sector.

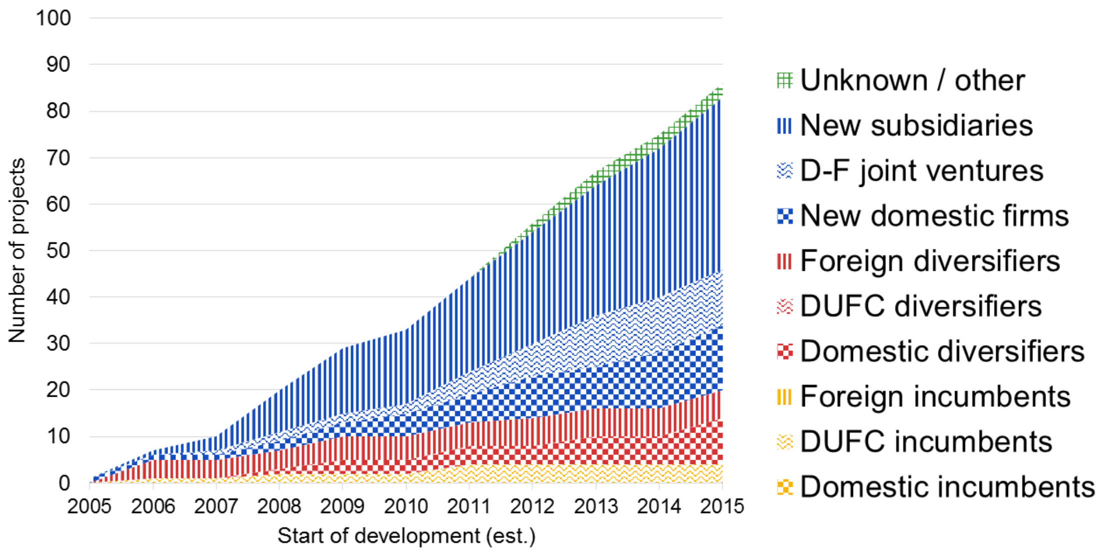

Figure 5.2: Project development in the Wind sector. *Only a share of these projects had gone to the investment stage by 2016. Projects are considered to have started their development from the moment they entered the SEIA. Source: own elaboration based on self-compiled projects database; the data is available as a table in Appendix B.*

[84] Communication from PPWL66 and PPNS01

[85] Available at walker.dgf.uchile.cl/Explorador/Eolico2/

Leaving aside the early but isolated *Alto Baguales* project from 2001, the early Wind project developers showed the first signs of activity in 2006, the year when they first started presenting projects to the SEIA (Figure 5.2)[86]. These first movers – whose contribution to the entrepreneurial function ought to be considered, as we have seen, more important (ceteris paribus) than that of latecomers (Hausmann and Rodrik, 2003) – were not a homogeneous group. In the group, however, the foreign element was better represented than the domestic: the first five movers included a DUFC incumbent, two foreign diversifiers, and two new subsidiaries[87]. The handful of fully domestic developers that were active in the sector and were contemporaneous to them didn't move as fast: the first to submit a project, which was a new domestic firm[88], did so only in 2008. Thus, the first movers – or at least the more effective ones – in Wind sector project development were a more foreign than domestic set of incumbents, diversifiers and new entrants.

As time went by, the prominence of foreign or only partially domestic organisations would stay much the same. However, despite their early activity, the participation of the incumbents – a group, recall, which included the main Chilean electricity utilities among its most eminent members, all sizable multi-project organisations whom not only developed but also sponsored projects – would quickly diminish relative to that of the diversifiers and the new entrants. The first of these, the diversifiers, were a set where the domestic and the foreign element were more or less even, but where one foreign firm was dominant: this was *Acciona*, the large multinational conglomerate of Spanish origin which manufactured its own aerogenerators (outside of Chile), and which had previously been active in some of the other infrastructure sectors of the country, building roads, bridges, and a few other things; the rest of the diversifiers were a disparate combination of domestic firms that developed just one or a few projects, plus one more foreign firm which only developed one.

The most important wind project developers, however, came to be the new entrants, particularly the foreign ones. By 2016, seventeen new subsidiaries of various origins had developed more than a third of all projects. Many of these were firms that, having been born

[86] The y-axis of this and the two next figures is 'number of projects' rather than 'aggregate capacity', which is what I use for the project sponsorship graphs. The reason is that developing, say, a 10MW project is often not so different than developing a 20 or 50MW one, and moreover projects that actually get built are often of a different capacity than they had been planned at their early stages. It thus makes more sense to proxy the contribution to project development by looking at number of projects rather than aggregate capacity, this not just for Wind but also for Solar and AD. Similarly, the x-axis is here 'start of development' rather than 'start of operation'. This time the rationale is that 'start of development' is a much better indicator of the moment in time when the tasks associated with project development were completed, again this not only for Wind but also for the other cases.

[87] *Acciona* (new diversifier, 2006); *Endesa* (DUFC incumbent, 2006); *Handels und Finanz* (foreign diversifier, 2006); *ENHOL* (new subsidiary, 2006); and *Rame/Seawind* (new subsidiary, 2007).

[88] *Eolica Talinay* (new domestic firm, 2008).

with the rise of the European and US Wind sectors, were driven to find outlets abroad when the 2008 financial crash and the ensuing recession debilitated their home markets (Koch et al., 2014). They were a combination of multi-project firms such as *Rame/Seawind* – a British subsidiary which independently developed projects and provided services for third parties; *Enel Green Power* – a giant Italian multinational utility which, for the most part, developed projects to build them on their own; and a number of smaller, single-project firms such as *Pattern Energy* from the US and the Spanish *Enhol*, firms which may later turn into multi-project organizations if their initial venture was successful – as was the case with *Pattern* – or cease their activities if it was not – as was the case with *Enhol*.

Although the market share of the other two kinds of new entrants was not as large as that of the new subsidiaries, they were not insignificant players. Far from this, one of the three D-F joint ventures that engaged in wind project development, *Andes Mainstream*, was, in fact, the most active developer of all, with ten projects; this firm would chiefly develop for third parties, but not for any third party: in general, their projects were developed with the objective of selling them to *Aela Energia*, a sponsor with which they formed a close association. As for the new domestic firms, this was a group of less than ten small, single-project firms born out of specific project opportunities[89], plus one multi-project, serial developer named *Consorcio Eolico*, which was the most active fully domestic one.

Discovery and Development in the Solar Sector

The discovery of locations with promising climatic conditions to build projects was much less of an issue for the Solar sector than for the Wind sector. This was largely because the solar radiation conditions of the *Atacama Desert* were excellent and did not vary as much from one place to another. Thus, the criteria for a good location had more to do with factors such as the proximity of transmission lines and the ease of acquiring land-use rights. This last a factor, land-use rights, was also less of an issue than it was for Wind, for large swathes of the *Atacama Desert* were owned by the government, which was an active supporter of solar PV projects and was more than willing to lease the land[90]. For the first developers, the question was thus not so much that of where would solar projects be good business, but – given the variability of the Chilean electricity prices and the rapid decrease in the cost of solar technology that was taking place as the sector was taking off – *when* they would become so. Thus, once the first projects – all of them small, non-committal ones –

[89] One of these, *Eolica Talinay*, had in fact two projects, but these were closely related.
[90] In (MinBienesNacionales, 2013), the government explicitly states its intention to facilitate developers' procurement of land-use rights, and provides detailed instructions about how to enact this facilitation to the relevant ministry staff.

proved viable, several dozens of new developers quickly became active, so many in fact that it took most by surprise. Only time can tell whether this rush of new project development was a speculative bubble, but this is likely: if all of the projects that had been developed by the end of 2016 were to be built, they would amount to more than 17GB of solar capacity, this in an electricity system which had, by the same date, altogether less than 21GB of installed capacity, and which had not yet developed the capabilities needed to export large quantities of surplus electricity to its neighbors.

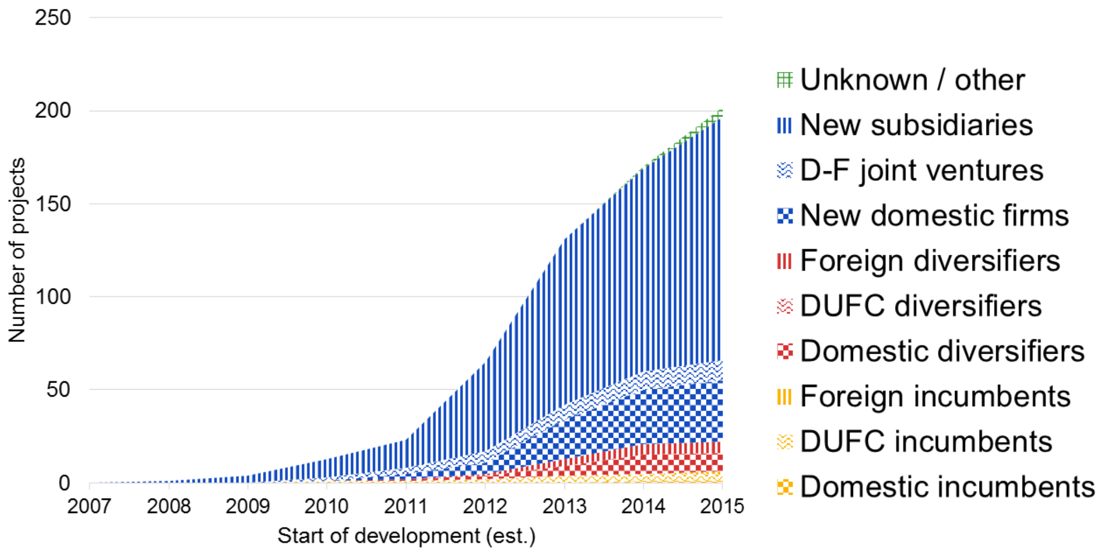

Figure 5.3: Project development in the Solar sector. *Only a share of these projects had gone to the investment stage by 2016. Projects are considered to have started their development from the moment they entered the SEIA. Source: own elaboration based on self-compiled projects database; the data is available as a table in Appendix B.*

As would continue to be the case in later stages, early solar project development was dominated by new entrants, especially foreign ones (Figure 5.3): three of the first five solar developers were new subsidiaries, and the other two were D-F joint ventures. Among the new subsidiaries was the same *Rame/Seawind* that was an active and prominent wind developer – a not an uncommon situation for wind and solar developers and also sponsors, many of which were active in both sectors. No incumbents or diversifiers were among the first five movers in this case.

The group of the new subsidiaries, which as we saw developed most projects, was composed of at least thirty-six different firms. A few of these, usually self-developers, were relatively large multi-project firms: the largest, *SunEdison*, had a staff of about eighty people and had by 2016 developed about fifteen. But the majority of these new subsidiaries were much smaller organisations, many of them single-project, though at least in some cases this was likely because of their recent arrival to the country.

The other sizable group of solar developers were the new domestic firms. This was a set of more than twenty firms, none of which was among the lead developers: the most active among them had by 2016 only developed three projects. Although, in the aggregate, they were not as relevant as the new subsidiaries, the group included *Valhalla*, which was arguably developing the most innovative solar project of all: a hybrid solar + pumped-storage hydroelectric development which was planning to make ingenious use of Chile's northern geography to solve, in a replicable way, one of the main issues with solar energy: its intermittency.

Discovery and Development in the AD Sector

The discovery of locations and contexts where anaerobic digesters could prove valuable was a part of the entrepreneurial function that fell more naturally to the AD sector sponsors than to its developers. Except for a few cases, anaerobic digesters were part of broader facilities (not necessarily industrial facilities: many of these were simply farms), and when they were not self-developments, third-party developers would be brought in as consultants by their sponsors early within the development stage. But to say that AD Sector developers did not play a part in the discovery of the opportunities that underpinned this sector is an overstatement: after all, AD Sector consultants depended on being hired by someone to stay in business, and in order to get themselves hired they would often, as one would expect, engage in the promotion of what they had to offer, taking active action to bring anaerobic digesters to the attention of prospective sponsors and to try to cast these as worthy and valuable investments[91].

[91] Communication by interviewee PPGY34

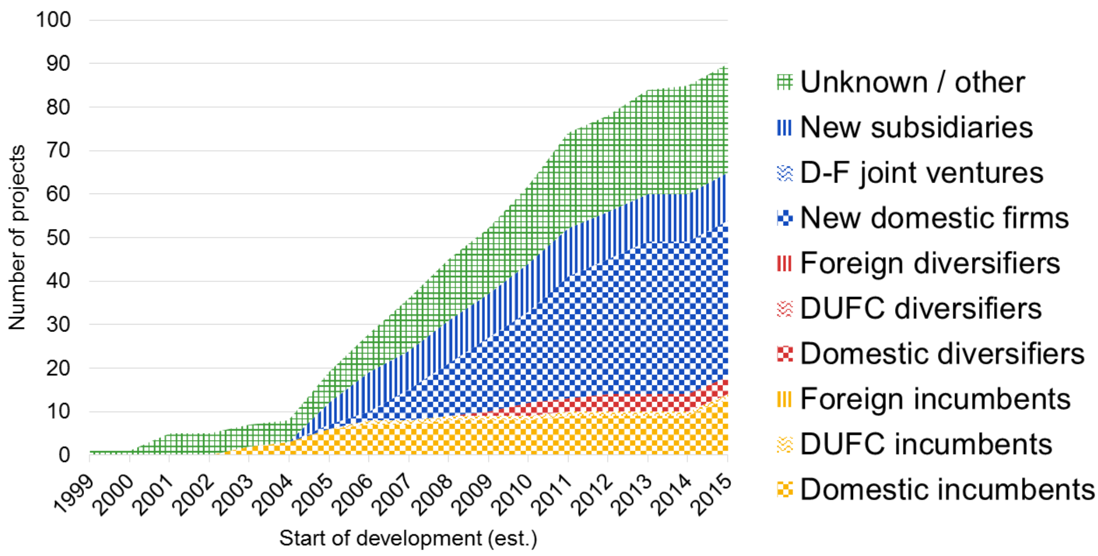

Figure 5.4: Project development in the AD sector. *Only a share of these projects had gone to the investment stage by 2016. As most AD projects did not go through the SEIA, their start of development date was equated with the earliest mention of them that I was able to find in my evidence base. Source: own elaboration based on self-compiled projects database; the data is available as a table in Appendix B.*

The first developer of anaerobic digesters of which I could find evidence was a foreign firm named *RCM*. This firm, however, was not a new subsidiary, as it acted as a foreign consultant and never established a permanent presence in the country. But a few years after this foreign firm had helped the first significant sponsor of AD facilities build five of these, other early developers became active. The first five that came after *RCM* were three domestic incumbents, one new domestic firm, and one new subsidiary. Leaving aside *RCM*, which was after all never a part of the domestic economy but rather a firm from which services were imported, the first developers of the Chilean AD sector – all of them consultants – were thus a more domestic than foreign group with a sizable participation of domestic incumbents – two of which were relatively large and diversified engineering service providers and one of which was a university.

Although incumbents were more significant than new entrants in early AD project development, the former group was soon surpassed by the latter, which was dominated by new domestic firms (Figure 5.4). This was a group of seven firms, none of which seems to have ever become larger than a dozen or so staff: a few of them, in fact, appear to have been one-man consultancies. Still, several of these were engaged in the development of not just one but several projects. At least four of these firms, and the three new subsidiaries that accounted for the rest of the projects developed by new entrants, had become inactive by

2016, in all likelihood because business had not gone well[92]. Seemingly, it was not easy to sustain an AD project consultancy business in the country.

As the majority of the new entrants, the few incumbents and the only diversifier that engaged in the development of these projects were all domestic firms. Thus, in contrast to what happened in Wind and Solar, the domestic developers were in this case dominant. The group of the incumbents was mainly composed of relatively large engineering firms – all multi-project organisations with previous experience in the WWT and often also the EG sectors – which expanded the portfolio of services on offer to their clients by developing capabilities in this new area. In the case of the lone diversifier, this was a remarkable self-developer named *Schwager*, which came from the mining services sector. This firm deliberately invested in the acquisition of AD-related technological capabilities, spending resources on research and pilot projects focused on adapting the technology to the local conditions and on finding it a suitable niche where it could be implemented. After years of technological learning efforts and a few false starts, by 2016 they had entered joint ventures with two domestic milk-processing firms to jointly sponsor three milk-processing facilities with integrated waste-processing and co-generating AD components which were a remarkable success and – in the Chilean context – a truly unusual one in its degree of inclusion of domestically-developed technology[93].

5.2.4. Sponsoring and Financing the Projects

In terms of the financial resources that were required, sponsoring a Wind or Solar project was a much larger commitment than developing one. In general, these larger commitments were made by either large domestic diversified groups or foreign MNEs, the firm types that dominate in HMEs (Schneider, 2013). In the case of the foreign MNEs, these would often sponsor several projects, especially when their core business was the provision of electricity. Sponsors of AD facilities, on the other hand, were in many respects different from Wind and Solar ones: they were far more diverse, going from the small farm to the large agribusiness; they were usually single-project; and their core business was often in areas that had little to do with waste treatment.

Sponsorship and Finance in the Wind Sector

The early sponsors of wind projects were all either domestic or semi-domestic firms: the first of them were a domestic incumbent, a DUFC incumbent, a domestic

---

[92] Communication from PPUX25 and PPOT34.
[93] Communication from PPNQ09.

diversifier and a D-F joint venture. The DUFC incumbent, which accounted for more than half of the aggregate capacity of the projects these early movers built, was the already mentioned *Endesa* – the first and still the largest of the country's utilities, originally a state-owned firm but by then already controlled by foreign capitals. This key player among Chile's utilities, a large multi-project self-developer, showed an early interest in wind farms and became a first mover in development and sponsorship through the establishment of *Endesa Eco*, a renewable energy projects arm. This early and promising initiative, however, came to a standstill when *Enel Green Power*, which is owned by the same Italian multinational that became the controller of *Endesa* a few years after *Endesa Eco* was established, arrived in the country and absorbed all of the activities of this last. With the disappearance of *Endesa Eco*, the participation of the incumbents dwindled, and by 2016 it hadn't recovered.

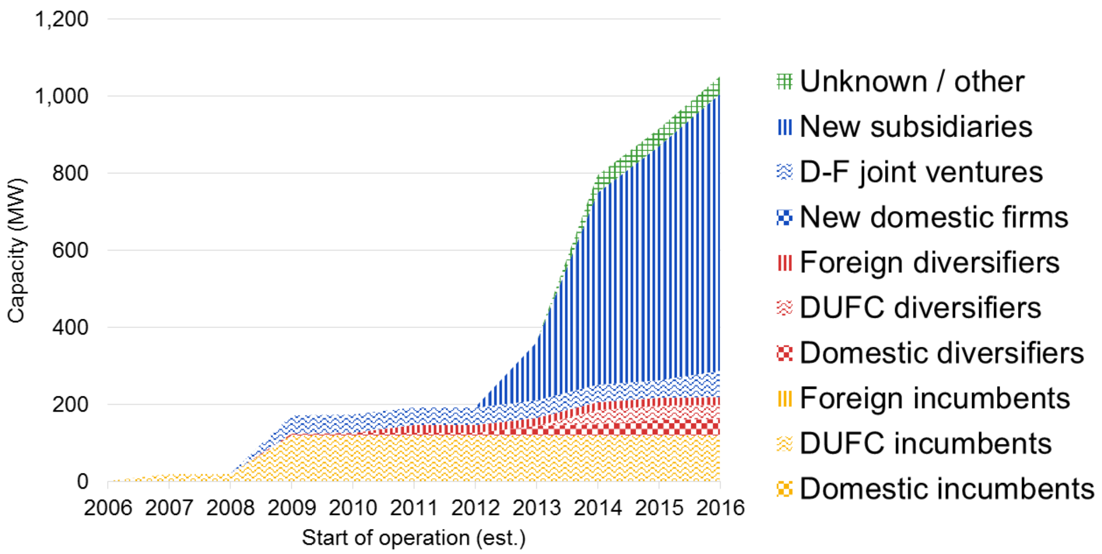

Figure 5.5: Project sponsorship in the Wind sector. *Source: own elaboration based on self-compiled projects database; the data is available as a table in Appendix B.*

For several reasons (most likely: the downward trend in the price of aerogenerators that started from about 2009, which made it reasonable to delay investments; the downward trend of energy prices, which cast doubts on the long-term income all EG facilities could generate; and the disappointing performance of some of the first wind projects, which was not good for the confidence of investors), Wind sector investment immediately slowed down after its take-off in 2009. As one can see in Figure 5.5, the recovery started in 2013, and its agents were largely the new subsidiaries: once these began to invest, they quickly surpassed all of the first five movers, none of which persevered with further investments. The most important among these new subsidiaries was the same *Enel Green Power* mentioned above, a firm which alone had sponsored almost half of the Wind sector installed capacity that was operational or under construction by the end of 2016. The other three new subsidiaries that had sponsored projects by then – a Colombian multi-sector utility that entered the sector by buying an independently developed project; a wind and solar self-developer from the US; a developer and service provider that self-developed one of its smaller projects; and the investment fund which was closely associated with the joint venture that became the most active wind developer – all made much smaller investments.

The average size of wind farms in Chile was relatively large and thus required fairly large sums of money. As is usually the case with large investments, the money came from a combination of equity from the sponsor and loans from finance providers. Large foreign MNEs such as *Enel Green Power*, and large domestic diversifiers such as *Antofagasta Minerals* did not have major problems raising these funds. But smaller firms with no financial backing had the usual disadvantages (Beck and Demirguc-Kunt, 2006), which as we've seen are accentuated in HMEs (Schneider, 2013). This was not just because of their smaller size and because the domestic financial system was reluctant to make loans for investments they were unfamiliar with, but also because, at the time, the NCREs were being actively discredited by some of the incumbents, which saw the renewable energies sector as a threat[94]. Some sponsors were able to raise money from international finance providers such as international development banks, which were interested in the diffusion of this new form of energy generation; but even these development banks proved more willing to finance the big players than the small ones[95].

Sponsorship and Finance in the Solar Sector

The early Solar sector sponsors were a set of firms which was significantly foreign but had some level of domestic participation: the first five of them were two new subsidiaries, two D-F joint ventures, and one DUFC incumbent. Led, as one can see, by four new entrants, this group built facilities which were fairly small relative to what would come later, indeed so small that their aggregate capacity of about 7MW is too small to be recognisable in Figure 5.6. The first moving solar sponsors were cautious: they all made small, tentative investments.

[94] Communication from PPHW74, PPZX82, PPWL66 and PPMM90.
[95] Based on information about the finance of projects from Bloomberg's New Energy database.

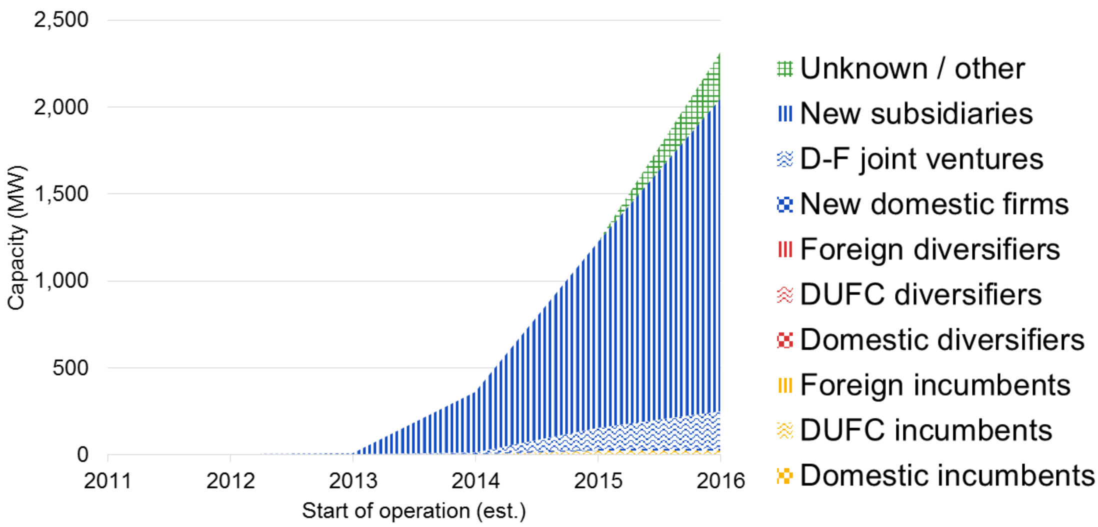

***Figure 5.6: Project sponsorship in the Solar sector**. Source: own elaboration based on self-compiled projects database; the data is available as a table in Appendix B.*

In the years that followed, Solar sector project sponsorship came to be almost wholly dominated by the new subsidiaries. By 2016, twelve of these, coming mostly from Europe, the US and China had built or were building more than two dozen projects, and more firms and projects were expected to come. The group was led by *SunEdison*, the US manufacturer/utility, whom, unlike the first movers, did not make a cautious but rather an aggressively entry[96], completing a large 94MW self-developed facility in 2014. The second largest market share belonged to *Enel Green Power*, the lead Wind sponsor, which was also active in this sector. These two leaders, however, did not have equally significant market positions in their main markets, for the level of concentration in the Solar sector was lower than it was in Wind: by 2016, the lead solar sponsor owned only 21% of the installed capacity, while the lead wind sponsor owned 43%. This lower market concentration was also reflected in the larger number of firms – most, as we've seen, foreign, and most not as large as *SunEdison*, but still often multi-project – that were sponsoring solar projects.

Finance for solar projects was much the same as it was for wind ones: much in need because of the relatively large size of the projects; far easier to acquire for larger than for smaller firms; and very hard to acquire from the domestic financial system. In better developed capital markets, the disadvantage of small firms in raising capital has often been alleviated through recourse to what is known as project-finance (Brealey et al., 1996; Esty, 2014), which are loans tied to a specific project which do not require collateral and which

[96] Perhaps too aggressively: on April 21, 2016, SunEdison filed for bankruptcy in the US.

are paid by the project's income. Project-finance, however, was largely unavailable from Chile's capital markets, and only one wind farm seems to have been financed through recourse to it[97]. This largely explains the absence of new domestic firms – which usually start small – from Solar sector and also Wind sector project sponsorship.

Sponsorship and Finance in the AD Sector

The first sponsors of anaerobic digesters were four domestic diversifiers coming from three different sectors (agriculture, swine raising, and alcoholic beverages production) plus one DUFC incumbent (a water utility). By far the most important among them was *Agrosuper*, whom we've already mentioned. This swine producer had already built seven projects by the time the fifth earliest mover completed its first one. *Agrosuper's* projects were not just more numerous, but also larger: they amounted to 91% of the capacity of the projects of the five early movers. And they, moreover, came much earlier: their first project was completed in 2001, whereas that of the second earliest mover came only in 2005. In terms of significance, this early sponsor was by far the most important.

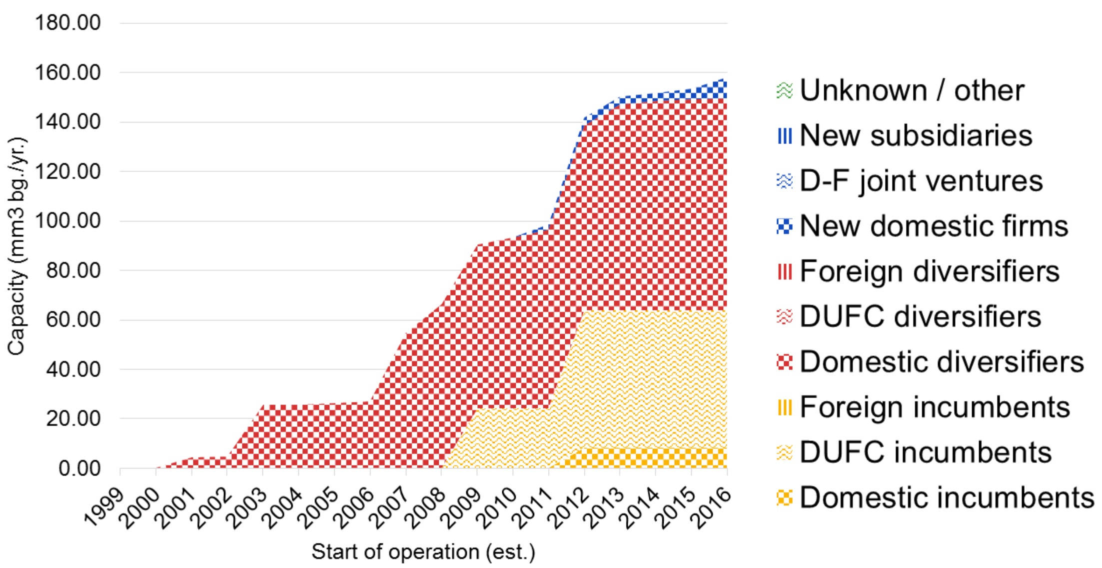

Figure 5.7: Project sponsorship in the AD sector. *Source: own elaboration based on self-compiled projects database; the aggregate capacity of projects is a very rough approximation, as data about projects' capacity was not as reliable as it was in the Wind and Solar sectors; the data is available as a table in Appendix B.*

[97] Indeed, the project manager of this project (PPEJ83) reported that arranging this project finance loan was his most difficult task and what he felt most proud of achieving.

As time went by, domestic diversifiers coming from different sectors kept their position as the most significant sponsors of these facilities (Figure 5.7). What these had in common was a) that they all ran waste-producing operations, needed to treat their residues, and could valorize them, e.g. by turning them into heat, electricity, manure, or CDM credits; and b) that it was technically convenient, or required from them, to do so within their facilities. In other respects, however, they were fairly varied. Like *Agrosuper*, a few were large livestock producers, but these last were eventually joined by smaller ones – as small, sometimes, as a farm of a few hundredth pigs or cows producing analogous but far smaller amounts of waste. Others, like the wine-sector services provider *Vinicas*, were food processing firms whose chief motivation was waste valorization rather than waste treatment. And yet some more came from the agriculture sector. Among these last was *HBS Energia*, whom sponsored the first large electricity generating anaerobic digester in the country, one that became operational in 2010. Most of these firms built just one digester, but a few of the ones that ran several production facilities built more.

One more significant group of AD sponsors were the incumbents. These were a very small set of just three firms, one domestic and two DUFC incumbents. They were, however, the sponsors of a large share of the anaerobic digestion capacity that had been built by 2016, and the reason for this was that two of them were very large facilities: *Aguas Andinas*, one of the two DUFC incumbents, was the largest water utility in the country, and its two facilities were by far the largest of the group, more than twice as large, in fact, as the third largest. These facilities were part of two large wastewater treatment plants that treated most of the wastewater of Santiago. Both generated significant amounts of biogas, which *Aguas Andinas* either sold or used to produce electricity.

Finally, two new domestic firms were the sponsors of four facilities. These amounted to a small, but not insignificant, share of the aggregate capacity. One of them was called *L&E*, a joint venture among the already mentioned diversifier *Schwager* – whom acted as the developer – and a firm whose core business was milk processing. And the other was *Genera Austral*, a firm that stands out because of its innovative business model: they would build digesters within the facilities of third parties but keep ownership of them, using them to generate electricity while their processed their partners' waste. Their case shows that it was not mandatory for anaerobic digesters to be sponsored by the owners of the facilities which they were usually part of, although this was by far the most common arrangement.

Anaerobic digestion facilities were generally much smaller investments than their wind and solar counterparts. Because of this, finance in this sector was not as much of a difficulty. Although the larger facilities were worth a few million dollars, the smallest cost probably no more than a few ten thousand or even less. Raising debt finance to build them was thus not really as common a practice as it was for large wind farms and solar PV systems: sponsors could more easily tap into their own resources to finance these investments.

5.3. Discussion

Above, we laid out with great detail the extent and the nature of the contribution that different kinds of entrepreneurial agent made to project development and project sponsorship in each sector. In this section, we will further our analysis by linking back these results with the theoretical considerations that, in Chapter 3, led us to distinguish between a) incumbent and new entrant entrepreneurial agents, b) domestic and foreign entrepreneurial agents, and c) independent developers, consultant developers, and self-developers.

5.3.1. Incumbent vs. New Entrants

As we saw in Section 5.1, new entrants to the Chilean Wind and Solar sectors benefitted from rising technological opportunities, low appropriability conditions, only modest cumulativeness conditions, and a knowledge base where the applied sciences were more important than the basic sciences. If technological regime theory is right, in these two sectors new entrants should have been expected to make a more significant contribution than incumbents to the entrepreneurial function (Breschi et al., 2000; Breschi and Malerba, 1997; Malerba and Orsenigo, 1993). In the case of the AD sector, the mixed knowledge base did not clearly benefit incumbents or new entrants. New AD sector entrants, however, did benefit from high technological opportunities and low appropriability conditions. Although, in this case, significant cumulativeness conditions gave some advantages to the incumbents, these advantages were arguably not higher than the benefits to the new entrants from the two other regime aspects. Thus, overall, the technological regime of the AD sector is also one where new entrants should have been expected to be more significant contributors to the function.

Table 5.2 summarises the actual contributions of these two groups, and the group of the diversifiers that falls within them, to the entrepreneurial function in each case. As shown there, what happened largely fits with what technological regime theory predicts. In most cases, new entrants were among the key players, gaining significant and in some cases overwhelmingly dominant positions as developers and sponsors.

		Wind	Solar	AD
Incumbents	Development	One of them was a first mover, but their overall participation was tiny.	None was a first mover, and they were not significant either in later stages.	They were the most significant first movers, and kept a small but sizable participation.
	Sponsorship	They were the most significant first movers, but did not persevere and were left behind.	Though there was one first mover, their overall participation was insignificant.	One of them was a first mover. They were few, and built few projects, but became fairly relevant because of the large size of these.
Diversifiers (Semi-Incumbents)	Development	They were among the first movers and kept a small but significant participation.	None was a first mover. Later they became active, but their overall participation was small.	None was a first mover. An innovative one became active later on, but their overall participation was small.
	Sponsorship	One of them was a first mover. They stayed active but their overall participation was small.	None was a first mover, and they had not yet sponsored projects by 2016.	They were the most significant first movers and overall became the most significant group.
New Entrants	Development	They were among the first movers and, overall, became the most significant group.	They were the most significant first movers, and were overall the most important group.	They were among the first movers and they became the most significant group.
	Sponsorship	None was a first mover, but they eventually took over and became the most important group.	They were the most significant first movers, and were completely dominant afterwards.	None was a first mover. A few became active later but their overall participation was very small.

Table 5.2: The relative contributions of incumbent and new entrant entrepreneurial agents to the entrepreneurial function. *Darker areas indicate more significant contributions. Contributions of early movers are considered to be more important than those of latecomers. The summary judgements encapsulated by the table are based on the data presented in Section 5.2.*

Several aspects of these results deserve further attention. One these is what probably is the main deviation from what the theory above predicts: the low significance of the new entrants in AD project sponsorship. As we've seen, only two AD sponsors were new entrants: *L&E* and *Genera Austral*. Although these two firms were among the most innovative of all, their overall participation was small. Ostensibly, the dominance of the incumbent sponsors in this sector – contra technological regime theory predictions – was directly linked to the nature of the demand for waste treatment services. As we saw in Section 5.1.2, demand for these services tended to be highly localised: because of regulatory and economic constraints, it was usually forbidden or uneconomical to provide these services too far from where residues were generated. By contrast, the design of the Chilean electricity market was such that, in principle[98], the provision of generation services did not need to take place near any specific consumption site. This, as we'll see, had significant repercussions.

As a consequence of the high localisation of the demand for waste treatment services, the sponsor>user transaction (see Chapter 3) in the AD sector was highly asset specific. In other words, the investments that needed to be made by sponsors in order to offer these services lost most of their value if the transaction did not take place with one single specific user: the owner of the broader facility (e.g. the waste treatment plant, the industrial swine breeding facility, or the cattle raising farm) within which the anaerobic digester needed to be built in order to provide the service economically and in compliance with regulations. In consequence, most sponsors of anaerobic digesters were also their users. Or, put another way, the most common way of organising the sponsor>user transaction in the AD sector was unitary governance (Williamson, 1981, 1979). Thus, it was exceptional for new entrant sponsors to invest in anaerobic digesters so as to provide waste treatment services to external users in exchange for a payment. *L&E*, one of the two exceptions, did not escape this reality: the digester they built was part of a broader, integrated milk processing facility which they themselves were going to operate. And *Genera Austral*, the other exception, was also not into the business of providing waste treatment services for external users: their anaerobic digesters were electricity-generating ones, and what they aimed for was to make a profit through the provision of generation services. But unlike these two firms, most of the users needing waste treatment services were previously existent firms, either incumbents which were upgrading their waste treatment facilities, or diversifiers which were building them for the first time (often to comply with tightening environmental regulations that they did not need to meet in the past, see Chapter 4). Hence, it was mostly incumbents or diversifiers that built these facilities. Thus, in line with other studies, features of the demand for waste treatment services had a significant impact on the pattern of innovative activity in the AD sector. But the feature that mattered in this case not the presence of network externalities (Shy, 1996; Windrum and Birchenhall, 2005), bandwagon effects (Sutton, 1991), demand heterogeneity (Adner, 2002), or experimental users (Malerba et al., 2007). Instead, it was the high localisation of demand that made the difference.

[98] Again, in practice, there were technical constraints, but this does not undermine the argument.

Although not in conflict with what technological regime theory predicts, the remarkably low participation of the incumbents in Wind and Solar is a second noteworthy feature of the results summarized in Table 5.2. After all, the features of the technological regime that favour the new entrants do not directly disfavour the incumbents other than by easing the way for their potential competitors. One may thus have expected them to show more interest and perform better. What the evidence suggests was behind their lack of interest was a case of what Leonard (1992) conceptualised as *core capabilities* turning into *core rigidities*. Though, particularly at the beginning, there were exceptions such as *Endesa*, the incumbents of the energy sector generally saw the renewables as an alien threat, in some cases, as we saw, going as far as mounting a discrediting campaign against them: there was gossip among some interviewees about at least one academic writing against the renewables sponsored by incumbents, and some of their executives would repeatedly cast them in the media as expensive, unreliable, and insecure[99]. Their core capabilities were in the conventional technologies, and, to their chagrin, for the most part they kept their bets on these. As for *Endesa*, we've seen how this leading incumbent was an important – indeed, probably the most important – early mover in Wind project development and sponsorship, but it later refrained. But the reasons why it did so are not the topic of this section: they are the subject of the next.

5.3.2. Domestic vs. Foreign

As we saw in Chapter 3, Schneider (2013) suggests dividing FDI into 'resource-seeking', 'market-seeking' and 'efficiency-seeking'. And argues that the extent to which a location attracts each kind will depend, respectively, on resource availabilities, market size, and production factor prices (especially wages). Regarding this classification, what little FDI there was to the AD sector was clearly market-seeking, and FDI to the Wind and Solar sectors also had clear market-seeking aspects: the MNEs that became active in all of these sectors, either as developers or sponsors, were clearly looking to expand the market where they could operate. But FDI to the Wind and Solar sectors was also, in some senses, resource-seeking: wind and solar radiation *are*, after all, natural resources; and although, in this case, FDI did not aim to extract something out of the country and sell it somewhere else (as it does in mining, the paradigmatic case), MNEs would not have become active in these sectors in the absence of acceptable – or, in the case of solar, outstanding – wind and solar radiation conditions. Thus the kind of FDI that went to all three sectors was market-seeking, but in the case of the Wind and Solar sectors it also had some resource-seeking overtones.

---

[99] Communication from PPHW74, PPZX82, PPWL66 and PPMM90.

Table 5.3 summarises the contribution of domestic and foreign (FDI) agents to the entrepreneurial function in each case. One can see there that, whereas foreign firms dominated Wind and Solar sector development and sponsorship, in the AD sector it was domestic firms that dominated both aspects of the function. Not being a large country, Chile should not, according to the above, be such an attractive destination for market-seeking FDI. Therefore, its prominence in the Wind and Solar sectors may at first seem surprising. However, there are a number of factors that explain it.

		Wind	Solar	AD
Domestic	**Development**	One of them was the earliest mover. Overall they gained a sizable but minority participation.	None was a first mover. Overall they gained a small but sizable participation.	They were the most significant first movers, and overall became the most important group.
	Sponsorship	One of them was the first mover, but they never really gained a significant participation.	None was a first mover, and their overall participation was insignificant.	They were the most important first movers and overall became the most significant group.
Semi-Domestic	**Development**	One of them was an important first mover. Overall they gained a sizable participation, but one that was smaller than that of the other two groups.	One of them was a first mover, but they never gained a significant participation.	None was a first mover, and they did not gain any participation at all.
	Sponsorship	They were the most significant first movers, but they stopped investing and were eclipsed by the foreign.	They were among the first movers, and overall gained a small but not insignificant participation.	One of them was a first mover. Overall they gained a large participation but only because of large size of their projects
Foreign	**Development**	They were the most significant first movers, and overall gained the largest participation.	They were the most significant first movers, and stayed as the most important group.	One of them was a first mover. Overall they gained a small but sizable participation.
	Sponsorship	None was a first mover, but they later became the most important group.	They were the most important first movers and then became the most significant group.	None was a first mover, and they did not gain any participation at all.

Table 5.3: The relative contributions of domestic and foreign entrepreneurial agents to the entrepreneurial function. *Darker areas indicate more significant contributions. Contributions of early movers are considered to be more important than those of latecomers. The summary judgements encapsulated by the table are based on the data presented in Section 5.2.*

The Electricity Generation sector, for a start, is a highly forward-linked sector (Hirschman, 1958), one whose output is used throughout the economy. Because of this, the sector tends to be sizable even in relatively small economies such as Chile's. Also, the utilities have historically been one of the main investment areas of FDI in Latin America, especially since the 1990s (Schneider, 2013, p. 117). Chile, moreover, is one of the most FDI-friendly lower-complexity countries in the world (Amsden, 2001). In addition, the take-off of these two sectors, as we've seen, took place just as the 2008 crash and ensuing recession hit many of the countries where they had previously been growing dynamically (Koch et al., 2014), pressuring the firms which had led the surge in those countries to look for new markets. Finally, a significant aspect of the government's strategy to develop these sectors was to attract FDI: CORFO, the main Chilean economic development organization, actively sought to attract FDI to these two sectors, organizing international talks, going to international trade fairs, producing brochures, and so on, all in order to lure Wind and Solar sector MNEs into the country (Diaz, 2010; Gomá, 2009; Rosende, 2010). It is, therefore, not surprising that MNEs were so active in these two sectors.

What is perhaps more puzzling is why domestic firms did not play more significant roles as Wind and Solar sector project sponsors, where they were the least important. That new domestic firms did not sponsor many projects, as we've seen, is unsurprising, for these had serious financial disadvantages (Beck and Demirguc-Kunt, 2006; Schneider, 2013) and did not have access to project finance (Brealey et al., 1996; Esty, 2014). And that domestic incumbents were not prominent is largely explained by the technological regime's favouring of new entrants (see the previous section), and by the fact that there were not so many domestic incumbents in the first place: like *Endesa*, the most important incumbents of the EG sector were DUFC. Domestic diversifiers, however, may well have played a much more important role as project sponsors: there were, after all, many domestic diversified business groups, of the kind common in HMEs (Schneider, 2013), which could have become sponsors of wind farms and solar PV systems. Given the fact that both the Wind and Solar sectors were full of independent project developers offering ready-to-build projects and willing to enter joint ventures to build them[100], lack of technological capabilities should not have been an insurmountable barrier. And given the fact that neither wind farms nor solar PV systems present the kind of economies of scale that give very large projects significant advantages over more modest ones, it was not just the largest of these groups that should

[100] Independent developers often kept (or hoped to keep) a small participation of the projects they sold (or were planning to sell) to sponsors.

have been able to finance them: the entrepreneurial opportunities were also open to the middle-range.

Were these diversified business groups, perhaps, crowded out by the newly arriving MNEs? With regards to the Solar sector, there are some grounds to make this case: in this sector, competition became fierce only a few years after the take-off[101], and the flood of MNE-sponsored solar PV systems led to serious transmission congestion issues which had an impact on the profitability of projects[102]. However, it is far from obvious that, had MNE solar sponsors from all over the world not swarmed to Chile from 2013, the groups would have taken their place. On the contrary: if one is to take the Wind sector as an example, the opposite seems far more likely. As one can clearly see in Figure 5.5, MNEs started to sponsor wind farms only from 2013 onwards, and before they arrived, the groups, which had had enough time to turn themselves into significant sponsors since the sector had taken off in 2009, had been anything but enthusiastic about the matter. Seemingly, then, and in line with their usual behaviour in HMEs (Schneider, 2013), the domestic business groups were just not as innovative as they could have been. If this is correct, the contribution of FDI to Wind and Solar project sponsorship was very positive, for it provided financial capital which would otherwise not have been forthcoming, and whose absence would have hindered the development of these two sectors and the benefits they brought to the wider economy[103].

A somewhat stronger case for crowding-out effects can be made for the domestic Wind and Solar sector developers. These, as we've seen, did make a much more significant contribution to this aspect of the entrepreneurial function in both of these sectors. Likely, at least in part, this was because this was an activity which was potentially open to all domestic economic agents, and not just to those with deep pockets (such as the business groups and the MNEs). In addition, wind and solar project development was, arguably, an activity that benefitted from a deeper knowledge of the local milieu[104], giving domestic firms

---

[101] Communication from PPCH11, among others.

[102] By 2016, serious congestions problems were driving SPOT prices to zero several times a week, and were obliging the network operator to instruct solar PV system operators to turn their power plants off, even when they had priority under the lowest-marginal-cost-comes-first rule. See, for example, (ANTUKO, 2015a, 2015b, 2015c).

[103] Along with strong and effective public policies by the latest administration, the rapid development of the Wind and especially the Solar sectors has been held responsible for the dramatic electricity price decreases that have recently taken place in the country, see www.bloomberg.com/news/articles/2016-06-01/chile-has-so-much-solar-energy-it-s-giving-it-away-for-free and www.df.cl/noticias/empresas/energia/ofertas-economicas-marcan-hito-en-procesos-de-licitacion-de-energia-y/2016-08-16/123510.html

[104] Developing these projects a) involved interaction with the government and thus knowledge about its bureaucracy and of the relevant regulations; b) involved interaction with landlords and local communities and thus knowledge about the socio-economic aspects of the localities; and c) benefited from knowledge about the local climate and geographical conditions.

an advantage over new subsidiary developers. If there was room for local bottom-up entrepreneurial initiative in these two sectors' early development processes – the kind of activity that could start-up in a garage and, after some years, end up in fancy offices in the business district – then this was it. And, as we've seen, there was indeed a substantial amount of such initiative. The domestic developers, however, did not surpass the foreign ones in either of these two sectors.

Were they crowded out? One fact that indicates so is that the supply of projects by developers far exceeded the demand from sponsors. Assuming wind and solar projects took three years to mature[105], we may easily calculate by how much: take the number of projects or MW built by year X, and divide it by the number of projects or MW that had started being developed by the year X – 3. If X = 2016, then a) only 33% of the wind projects (or 13% of the wind MW) that had been developed by 2013 had become operational by the year they had matured (2016); and b) only 31% of the solar projects (or 22% of the solar MW) that had been developed by 2013 had become operational by the year they had matured (2016). This large oversupply indicates that foreign developers may indeed have crowded out domestic ones in these two sectors. If so, one may make the case that this was justified because these foreign developers may have had more highly developed capabilities than the domestic ones, leading to better projects and, more generally, to knowledge spillover effects (Nieto and Quevedo, 2005). If this case is granted, it is difficult to say[106].

The clearest case of crowding-out effects in these two stories, however, was the displacement of the DUFC incumbent *Endesa* by the new subsidiary *Enel Green Power*. As we've seen, *Endesa*, the first and most important of the Chilean utilities, pioneered the Wind sector – and may, on time, have pioneered the Solar sector – through the early establishment

---

105 This is an approximation, but not an unreal one: the actual maturity time of Chilean wind and solar projects by 2016 (from the moment they entered the SEIA until the moment they entered operational) were, by my calculation, 1,281 and 1,039 days, respectively.

106 According to one interviewee (PPWE35), domestic projects were often of a lower quality than foreign ones, and many of the firms that developed them did so in the hopes that they could trick a foreign sponsor into buying them by hiding their weaknesses until it was too late. However, few sponsors invested in projects without having these go through a due diligence check. Therefore, if this was the case, one would expect projects developed by foreign firms to be more likely to be built than those developed by domestic firms, as due diligence on the supposedly 'bad quality' domestic ones would have discarded them. Although the figures match the interviewee's opinion in the case of Solar, they do not match it in the case of Wind: 32% of the wind projects developed by foreign firms by 2013 had become operational by 2016, compared to 38% of those developed by their domestic counterparts; and b) 31% of the solar projects developed by foreign firms by 2013 had become operational by 2016, compared to 23% of those developed by their domestic counterparts. But in the case of solar projects, one must remember that the large majority were sponsored by foreign developers, which a) often self-developed their projects, and b) may have been biased toward favoring projects developed by new subsidiaries. It is therefore not clear at all that the impression of the interviewee was representative of the real situation.

of an NCRE subsidiary, *Endesa Eco*. Being part of a multinational which is active in several other Latin American countries, *Endesa Eco*, had it kept going, may have become a significant renewable energies player, not just in Chile but in Latin America, and maybe eventually in the World. But this was not to happen: in the year 2009, the multinational Italian utility *ENEL* became the controller of *ENDESA*, acquiring a 60% of its shares; soon after that, its NCRE arm *Enel Green Power* – which is not partly domestic but fully foreign – arrived in the country and absorbed all of the assets of *Endesa Eco*, which then disappeared. With the crowding out of *Endesa Eco* by *Enel Green Power*, the best chance of growing a domestic global player in the NCREs disappeared.

Turning our attention to the AD sector, the main question, in this case, is why foreign and semi-foreign firms made such limited contributions to both parts of the entrepreneurial function. As with the incumbent / new entrant sponsors balance, the key to understanding why so few foreign or semi-foreign firms sponsored AD projects lies in the localised nature of the demand for waste treatment services. As we've seen, this forced the users of this service to become themselves the sponsors of the facilities needed to provide it. The set of potential sponsors of most of these facilities was thus not as boundless as it was in Wind and Solar, but was rather limited to firms running waste-generating operations and to waste-treatment utilities. Most of the former were domestic, and the largest of the latter were semi-domestic, which explains why only firms from these two groups sponsored them[107].

The above, however, does not apply to the realm of project development. The fact that AD facilities were normally sponsored by their users need not have discouraged foreign firms from entering the sector as consultant AD project developers. As we saw, however, very few did: only four of them, apparently, since the first AD project about which I could find information started to be developed in 2001, until 2016. Why was this so? Although we can only speculate, three seem to have been the most important reasons. First, the small size of the market (in terms of the value of the investments, more than an order of magnitude smaller than the market for wind farms and solar PV systems, as we saw in Chapter 4, Section 4.1), which made it difficult to sustain an independent AD-project development business[108]. Second, the high diversity of this market, which made success

[107] AD facilities that did generate an independent income, e.g. by generating electricity, were of course possible. However, the LCOE of biogas-based electricity generation is not very competitive, as Figures 4.8 and 4.16 from the previous chapter show. Hence, biogas-based electricity generation is usually justified only if the facilities serve the additional purpose of waste treatment.

[108] 'Independent' in the sense of exclusively dedicated to this activity. As we've seen, several of the domestic firms which tried to do so failed. And those that survive are rarely fully dedicated to AD

hinge on knowledge about the domestic economy and the waste treatment needs of its waste-generating industries, thus benefiting domestic firms better acquainted with the local milieu. And third, the fact that only parts of the global WWT sector were as international as the EG sector: except for the larger city WWT utilities, WWT MNEs were arguably not as common as EG MNEs. Thus, the nature of its demand and the global context seem to have made AD sector project development an activity more amenable to domestic actors. CORFO, which over the years also provided some support to the development of this sector, seem to have been aware of this, for most of its activities – commissioning some studies of AD potential (GAMMA INGENIEROS, 2011), financing at least one technology tour (CORFO, 2009), and later creating a program for the promotion of small-scale AD facilities for dairy farms[109] – were geared toward the support of local actors, rather than to the attraction of foreign ones.

5.3.3. Modes of Development

In Section 5.2.1, we saw how the way in which developers and sponsors related to each other varied significantly among the three sectors: while AD sector developers were usually consultants, Wind and Sector ones were for the most part self-developers or independent developers. We also saw there that these differences had significant implications: in one important sense, the independent developers of the Wind and Solar sectors contributed more to the entrepreneurial function than the consultant developers of the AD sectors. But what explains their ascendancy in the former two sectors, and their absence in the latter?

As with the relation among the users of the waste treatment service and the sponsors of the facilities that provided it, the key to the matter lied in the high potential for opportunistic behaviour in the developer>sponsor transaction in the AD sector. Much like the investments that AD facility sponsors needed to make in order to support their transactions with AD facility users, the investments that AD sector developers needed to make in order to be able to develop a project – in things like lab studies to characterize the substrates, environmental impact analyses, plant designs, etc. – were highly asset specific. These investments, too, lost most of their value if the transaction with one specific sponsor – the owner of the broader facility where the anaerobic digester would usually be built –

consultancy: more often, they are broader consultancies, with capabilities in this area but also in many others.

109 www.quepasamineria.cl/index.php/vida-e-innovacion/item/3992-el-biog%C3%A1s-se-toma-el-sur-de-chile-y-aborda-a-la-industria-lechera

ended up not taking place. Naturally, this made AD sector developers reluctant to develop projects independently (Williamson, 1981, 1979).

Things were much different for the Wind and Solar sector developers. In their case, development stage investments did have *some* degree of asset specificity, but not in relation to their transactions with sponsors: their investments were asset specific in relation to their transactions with the landowners of the locations where they were planning to develop projects. These transactions were necessary because developers were often not landowners, but rather scouts in search for attractive project locations. When they found such locations – which, in itself, required investing some time and money – they needed to convince the landowners to partner with them to develop a project. In order to lure them into this, the developers would sometimes go as far as undertaking detailed wind or solar resource measurements – which took more time and money – so as to convince them (and confirm to themselves) that their land was a potentially attractive project location. This opened the door to opportunistic behaviour from the part of the landowners, for the very act of being contacted for such a purpose signalled to them that their land had a value that they may have previously been unaware of – especially so if they were shown resource measurements that proved it. Such opportunistic behavior did sometimes take place, and some landowners (or owners of mining rights, which were legally distinct from land rights) ditched the developers that had initially contacted them in order to develop the projects by themselves, or to shop around for the highest bidder for the land that they now knew was more valuable than they had imagined[110]. Developers, however, had their own bargaining chips. They, for a start, could sometimes knock the door of an adjacent landowner, which may be sitting on a similarly attractive location. They, moreover, would normally already have the capabilities to develop the projects, whereas the landowners would usually not. And they, finally, could hedge their bets by developing several projects in parallel, periodically evaluating their portfolio's prospects, and investing resources in moving forward only those projects that looked promising. Hence, developers did regularly succeed in partnering with landowners. And once they had done so, they were free to independently develop projects which could be sponsored by anyone.

Thus, the absence of independent project developers from the AD sector, and their presence in the Wind and Solar sectors, can be explained in terms of transaction costs theory (Williamson, 1981, 1979). But can the theory also account for the prevalence of self-developers over independent developers in these last two sectors (Figure 5.1)? In part, it

[110] Communication from PPWL66, PPNS01, PPOL73, and PPWE35.

can. As we've seen, the development>sponsor transaction in the Wind and Solar sectors was not highly asset specific, meaning the value of development stage investments was not greatly diminished if any specific economic agent was not interested in sponsoring a project, and leaving the door open to the emergence of a market for independently developed projects. However, the potential economies of scale to be gained from the concentration of project development activity into specialised firms supplying projects to the market were arguably not so significant. After all, the marginal costs of conducting complex negotiations with landowners, environmental impact studies, and detailed resource measurements; of designing facilities; of evaluating alternative technology suppliers; and of other development stage activities were probably not much higher for the first of a developer's project than they were for subsequent ones. Not nearly as high, in any case, as is the marginal cost of producing the first bolt compared to the next ones.

In addition to the limited potential for economies of scale of project development activity, the relatively high uncertainty of the developer>sponsor transaction also diminished the attractiveness of market governance. Evaluating ex-ante the quality of a Wind or Solar project was costly and difficult. Indeed, some of the ancillary services firms that appeared in these sectors were firms whose business was to undertake these *due diligence* evaluations[111]. Furthermore, the developer>sponsor transaction was typically a one-off transaction, which made sponsors vulnerable to opportunistic behaviour by unscrupulous developers, which, knowing they were unlikely to engage in more than one transaction with any given sponsor, may be willing to offer bad quality projects on the market[112]. Developers, moreover, were often single-project organisations put together for the specific purpose of developing one project, meaning the reputational damage that may result from selling a bad quality project to a naïve sponsor would not cause great harm. In sum, although the low asset specificity of the development>sponsor transaction in the Wind and Solar sectors made independent project development *possible*, its low frequency, its high uncertainty, and the limited potential for economies of scale of this activity did not make this way of organizing it such an overwhelmingly superior option (Williamson, 1981, 1979).

Transaction costs theory, however, ignores an important factor that may also have underpinned the ascendancy of self-development in the Wind and especially the Solar sectors, and that may moreover explain why it was consultant developers, rather than self-

[111] Interviewee PPKL99 was a Spaniard that arrived in the country and, building on his experience in the Spanish NCRE sector, started up on such due diligence firm.

[112] As mentioned on a previous footnote, one interviewee (PPWE35) was of the opinion that such unscrupulous developers were abundant.

developers, that dominated in the AD sector: the capabilities of the potential developers (Bell, 2009). The Wind and Solar sectors, as we have seen, were populated by newly arriving foreign sponsors as they were taking off (Solar, Figure 5.6) or soon after (Wind, Figure 5.5). Notably, many of these new subsidiaries were not just any firm: they were highly capable Energy sector firms backed by a wealth of experience in other countries' Wind and Solar sectors. Hence, their capabilities may well have been as important a reason for the decision of many of them to develop their own projects as the transaction costs explanation developed in the previous paragraphs. The sponsors of AD facilities, on the other hand, did *not* normally have capabilities related to anaerobic digestion technology. As we have seen, most of these sponsors were the users of the facilities themselves. And, save the WWT utilities, their core business was usually *not* to treat waste: most were engaged in some form of manufacturing activity that required waste treatment services. Focused as they were on their core business, few of these developed in-house capabilities in the area of anaerobic digestion, and hence needed to hire consultants to help them with this. This shows how, as Williamson himself has noted (Williamson, 1999), transaction costs theory and the resource-based view (Mahoney and Pandian, 1992; Nelson and Winter, 1982; Penrose, 1959) are complementary rather than rival theories of the firm.

5.4. Wrapping Up

In this chapter, we sought to illuminate the reasons why certain kinds of entrepreneurial agents made more significant contributions than others to the entrepreneurial function in the Chilean Wind, Solar and AD sectors. The goal of our analyses was also to understand how the nature of the contributions that different agents made varied, and the consequences of these variations.

The chapter started by going through a number of features of the broader sectors within which the three under study emerged (the EG and the WWT sectors) which past research suggests are significant determinants of the pattern of entrepreneurial activity: the global context of these broader sectors, the nature of their local incumbents, their technological regime, and the nature of their demand. Regarding the global context, we argued that while the global Wind and Solar sectors were highly international, the global AD sector was not so much. Regarding the incumbents, we saw how public and private utility companies, many of which were controlled by foreign capitals, were among the most prominent incumbents in all three sectors; and how, in the case of the AD sector, many industrial firms running waste-generating activities were also among the incumbents. Regarding the technological regimes, we found that the Wind and Solar sector regimes were characterized by rising technological opportunities, low appropriability conditions, moderate cumulativeness conditions, and a knowledge base rooted on the applied sciences; and the regime of the AD sector was also characterized by rising technological opportunities and low appropriability conditions, but had high cumulativeness conditions and a knowledge base rooted in both the basic and the applied sciences. And regarding the nature of the demand for what the facilities under study were able to provide, we saw how the most salient feature of the demand for generation services were its complexity and its localisation, and the most salient features of the demand for waste treatment services were its diversity and its localisation.

Having done this, we then moved to the main section of the chapter. Here, we went through a detailed account of the contributions that different kinds of economic agent made to the two main aspects of the entrepreneurial function in infrastructure sectors: the discovery of specific entrepreneurial opportunities and their development into viable investment projects, and the sponsorship and finance of these investment projects. In order to provide this account, we split firms into nine categories that were underpinned by two distinctions of theoretical interest: that between incumbent and new entrant, and that between foreign and domestic entrepreneurial agents. We found that a) the biggest contribution to the function on the Wind and especially the Solar sectors, in both project development and project sponsorship, was made by new entrants, a majority of which were foreign; and b) the biggest contribution to AD sector project development was made by new entrants who were mostly domestic, while the largest contribution to sponsorship on this sector was made by domestic diversifiers, though the DUFC incumbents were also very important. In this section we also saw that the nature of the contributions that the project developers made in the Wind and Solar sectors was substantially different from those that they made in the AD sector: while, in the former, the developers were a mix of self-developers and independent developers, in the latter they were for the most part consultants, which meant their activity was in one important sense less risky and therefore less entrepreneurial (Hausmann and Rodrik, 2003; Lumpkin and Dess, 1996).

In the last section of the chapter, we went on to further discuss how these results linked back to the theoretical considerations that had led us to distinguish between a) incumbent and new entrant entrepreneurial agents, b) domestic and foreign entrepreneurial agents, and c) independent developers, consultant developers, and self-developers.

With regards to the first of these points, we saw how the dominance of new entrants in most respects largely coincided with what technological regime theory would lead one to expect (Breschi et al., 2000; Breschi and Malerba, 1997; Malerba and Orsenigo, 1993). An important exception to this was the dominance of incumbents and diversifiers in AD sector project sponsorship, which was contra technological regime theory predictions (in its original formulation). As we saw, in line with a number of studies that link features of demand with the pattern of entrepreneurial activity (Christensen, 1997; Malerba et al., 2007; Malerba and Nelson, 2011), this exception could be well accounted for by the localised nature of the demand for waste treatment services. This made the sponsor>user transaction a highly asset specific one, favouring the governance solution in which sponsors of AD facilities were typically the users of the waste treatment service themselves (Williamson, 1981, 1979). As one would have expected, most of these were incumbents or diversifiers, thus explaining the anomaly. Also regarding this point, we saw how the remarkably low participation of the incumbents of the EG sector in the development of the Wind and Solar sectors seems to have been due to, at least in some cases, their core capabilities turning into core rigidities (Leonard, 1992).

Concerning the distinction between domestic and foreign contributions to the entrepreneurial function, we noted that the high level of foreign participation in the Wind and Solar sectors was eased by Chile's open stance to FDI (Amsden, 2001), by the international character of these two sectors, and by FDI-attraction policies. We then saw that, while Wind and Solar sector MNEs probably did not crowd out (Agosin and Machado, 2005; Amsden, 2009) domestic sponsors, they may have crowded out domestic developers, and they definitely crowded out a DUFC incumbent: *Endesa Eco*. With regards to the AD sector, we saw how the localised nature of the demand for waste treatment services, and the fact that most of the waste-generating firms that needed them were domestic or semi-domestic, were the reasons for the low presence of foreign sponsors. And we also saw how the limited market for anaerobic digesters, its high diversity, and the lesser degree of internationalisation of WWT sector MNEs were the most plausible causes of the low degree of foreign participation in project development.

In relation to the dominance of different kinds of developers in sectors we studied (independent and self-developers in the Wind and Solar sectors, and consultant developers in the AD sector), we saw that transaction costs theory could explain much of the results (Williamson, 1981, 1979). Thus, the absence of independent developers in the AD sector seems to have been a result of the high asset specificity of the AD sector developer>sponsor transaction, which was, in turn, a consequence of the localised nature of the demand for waste treatment services. Furthermore, the fact that, although independent developers had a significant presence in the Wind and Solar sectors, they did not dominate over the self-developers, could also be explained in terms of transaction costs reasoning: although the low asset specificity of the developer>sponsor transaction in these sectors opened the door to independent project development, its high uncertainty, its low frequency, and the limited potential for economies of scale in project development activity did not make this such an overwhelmingly superior way of organizing the activity. However, regarding this matter, we also saw how a) the prevalence of self-developers in the Wind and Solar sectors was also likely due to the typically high (Wind and Solar sector-related) capabilities of the new subsidiary sponsors that populated these sectors, many of them international energy sector utilities; and b) the absence of self-developers from the AD sector was likely due to the usually low (AD sector-related) capabilities of the typical sponsor of anaerobic digesters, whom as we have seen was not normally a firm for whom waste treatment was its core business, but rather a manufacturer that needed the waste treatment service for its internal operation. This, as we saw, shows how transaction costs theory (Williamson, 1981, 1979) and the resource-based view of the firm (Mahoney and Pandian, 1992; Nelson and Winter, 1982; Penrose, 1959) complement each other (Williamson, 1999).

With this, we finish the chapter on the entrepreneurial function, and move to the next one, which deals with some important matters that we have only scratched the surface of: domestic capabilities and access to foreign skills.

Section / Concept	Operational Assumptions / Operational Definitions	Methods / Data
General	- **OA:** The process of emergence of the sectors under study is part of the process of transformation of broader sectors.	- **D:** Self-compiled projects database. - **D:** Secondary documents. - **D:** Scoping interviews.
Section 5.1.	- **OA:** The Wind and Solar sectors are mainly part of the Electricity Generation sector, and the Anaerobic Digestion sector is primarily part of the Waste and Wastewater Treatment sector.	- **D:** Secondary documents. - **D:** Scoping interviews. - **M:** Weighing of the available evidence base.
Section 5.2.	- **OA:** In infrastructure sectors, the entrepreneurial function consists of a) discovering specific entrepreneurial opportunities and developing them into viable investment projects, and b) sponsoring and financing (building) these investment projects. - **OA:** The transition from the development to the investment stage of projects a) roughly corresponds with the two parts of the entrepreneurial function in infrastructure sectors, and b) is technologically separable and can, therefore, be analysed as a transaction. - **OA**: The first five firms to develop or sponsor projects are the 'first movers'.	- **D:** Self-compiled projects database. - **D:** Scoping interviews. - **M:** Weighing of the available evidence base.
Section 5.3.	- **OA:** Larger market shares signify larger contributions to the entrepreneurial function. - **OA:** First movers contribute more to the entrepreneurial function than latecomers.	- **D:** Self-compiled projects database. - **D:** Scoping interviews. - **M:** Weighing of the available evidence base.

Table 5.4: Summary of data, methods and operational assumptions/definitions used in Chapter 5.

Chapter 6

Domestic Capabilities and Foreign Skills

What was the nature of the sectoral-level aspects of the processes of accumulation of capabilities that took place as the Chilean Wind, Solar and AD sectors developed?

What influenced the extent to which the capabilities of the entrepreneurial agents of these sectors came to depend on their ability to tap into the skills of foreigners?

As we saw in Chapter 3, the capability of economic agents to undertake any complex economic undertaking hinges on their ability to access various forms of capital, among which physical, knowledge, organisational, and human capital are crucial (Bell, 2009). As also noted in that chapter, when analysing the development of a new sector, it is convenient to distinguish among the non-sector-specific, sector-specific, and firm-specific parts of this capital. This is because, although the capabilities of the entrepreneurial agents of a sector may hinge on their ability to access capital at these three levels, it by characterising the sectoral and firm level accumulation processes that we can better understand how the sector developed.

In trying to understand the nature of the process of development of capabilities that took place as the Wind, Solar and AD sectors emerged, we therefore leave out of the analysis the question of how non-sector-specific capital became accessible to their entrepreneurial agents. This is despite the fact that, without access to capital at this level, the development of any of these sectors is difficult to conceive: the entrepreneurial opportunities underpinning each sector could hardly have been pursued without access to things such as a) ports to receive imported capital goods, roads to transport them, transmission lines to move electricity, etc. (physical capital); b) knowledge about the climate of the country, topographical maps, general knowledge about the waste treatment needs of different cities and regions, etc. (knowledge capital); c) general economic regulations, trade agreements, etc. (organizational capital); and d) the general skills of the thousands of active workers that were available to be hired by the firms of the sector (human capital).

What follows, therefore, is an analysis of how key sector-specific and firm-specific forms of capital, on which entrepreneurial agents' capabilities were built, became accessible to them. In the first section, we will go through an account of the principal sectoral-level capability accumulation events that took place as each sector was developing – or, in some cases, even before their development process became noticeable. As we'll see, these events infused the Wind, Solar, and – to a lesser extent – AD sectors with forms of capital – in most cases, organisational capital – which was not specific to any of its entrepreneurial agents but which was nevertheless important to the development of the sectors.

At the level of firm-specific capital and capabilities, our analysis, to be carried out in the second and largest section of this chapter, will only be partial, for a comprehensive account of how entrepreneurial agents developed their capabilities is outside the scope of this study. Therefore, we will assume that, as tens of developers and sponsors entered each of the sectors, they brought with them – or accumulated in the way, or gained access to – the various forms firm-specific physical, organizational, and knowledge capital that they needed to access in order to pursue the entrepreneurial opportunities, and inquire only about how they accessed the *human capital* – the highly skilled workers – they needed to operate. Our analysis of human capital, however, will also be limited, for we will not inquire about internal training programs and other key means by which developers and sponsors may have gained access to the high skills they needed. Instead, our focus will be the relative extent to which the skilled workers they relied upon came from foreign countries rather than from the domestic labour market. As we saw in Chapter 3, this issue is highly relevant for new sectoral emergence processes in HMEs, this because these economies tend to be trapped in low-skills equilibriums, and because domestic skills shortages may be expected to be even more common when the activities requiring the skills are novel. Understanding how entrepreneurial agents were able to access these skills is thus crucial to understanding how the new sectors developed – and, as we'll see, tapping into the skills of foreigners was one of the main mechanisms by which they did so.

6.1. Building Domestic Capabilities at the Sectoral Level

Many researchers agree that the most important part of the capabilities of a sector are the capabilities of its individual firms, either explicitly as in (Bell, 2009), or implicitly as in studies of sectoral capabilities that for the most part focus on specific firms (e.g.

Iammarino et al., 2008; Marin et al., 2014). In all likelihood, the Chilean Wind, Solar and AD sectors were no exception: arguably, the most important aspect of the process of accumulation of capabilities that took place as these sectors developed was the entry to them of the developers, sponsors, and ancillary service providers that contributed to the pursuance of the respective entrepreneurial opportunities, and their internal capability development processes. But as the literature of innovation systems has shown (Freeman, 2002, 1987; B.-A. Lundvall, 1992; Malerba, 2004; Malerba and Nelson, 2012), sectors are usually more than the firms that compose them, and this is at least partly because they often develop capabilities at the sectoral level.

What follows is an account of the most salient events of the process that led to the formation of these sectoral-level capabilities. Although it is not comprehensive, the account – constructed from interview notes and secondary documentation – includes some of the key sectoral-level capability-development events for each case, and provides a first approximation of the nature of these capabilities and of the processes that led to their formation. In the case of the Wind and Solar sectors, all of the events were common to the two, which is arguably a consequence of their both being NCRE sectors that developed in tandem. In the case of the AD sector, there is just one event, which suggests that this sector, perhaps because of its small size, did not develop as much of a 'sectoral identity' as did Wind and Solar. In most cases, what these events contributed to the sectors was non-firm-specific organisational and human capital, although there were a few instances where they added to the common pool of knowledge capital.

The Rural Electrification Program (Wind and Solar)

At the beginning of the 1990s, more than 50% of the rural population of Chile did not have access to electricity. This situation prompted the government to create what came to be known as the *Rural Electrification Program (REP)*, which was to be managed by the *Comisión Nacional de Energía (CNE)*, and whose objective was to provide electricity to these rural areas. By 2005, under the aegis of this program, the large majority of households in these areas had been provided electricity through extensions to the electricity distribution network. A small share, however, of about 348 households representing 1.4% of the total had been provided electricity through off-grid self-generation facilities, most of these solar or wind ones which were sometimes combined with diesel generation systems. The low share of rural households that the program had provided a solution for using self-generation systems rather than extensions to the network was disappointing to the authorities, this because the rural households that had yet to be connected were the most isolated and thus could only be provided for using these systems: extensions to the network were not viable. Thus, the future of the program depended on the self-generation solution, and as this had not become as common, it needed to be fostered. It was in this context that, in 2001, the REP was strengthened by a *United Nations Development Program (UNDP)* sponsored subsidiary project called the *Barrier Removal for Rural Electrification with Renewable Energies project (Barrier Removal Project)*. This project was jointly run by the CNE and the UNDP, and was partly financed by the *Global Environment Facility (GEF)* (DIPRES, 2005).

The REP and the Barrier Removal project sowed the very first seeds of what later became the Wind and Solar sectors in the country. The first of these initiatives, although small in financial terms, played what was arguably a significant knowledge diffusion role[113]: through the creation of regional technical units tasked with supporting the projects, the organization of talks and workshops, and the provision of training to private actors, the program brought wind and solar technologies to the attention of thousands of people that were unfamiliar with them, a number of which would later come to be involved in the respective sectors (Navarro et al., 2005).

The Barrier Removal Project made an equally or perhaps even more important contribution to the capabilities of the sector through the pursuit of a concrete nine-point barrier-removal agenda that addressed specific issues. Among these was the 'lack of standards for RE equipment', the 'lack of certification procedures for RE systems and their installation', the 'lack of general knowledge with respect to renewables', the 'lack of formal training programs', the 'perception of risk associated with RE technologies', and the 'lack of technical, equipment and analysis capacity for wind resource measurements' (Rodriguez, 2012, pp. 10–11). According to this evaluation report, the pursuit of this agenda was highly successful. The author of the report argues that the project 'left an important array of standards, certification procedures, didactic materials … guidelines on creating cooperatives for the promotion and development of power projects and methodologies for RE project evaluation', among others things – all of which, according to him, 'contributed to building capacity'. The beneficiaries were 'trainees, staff from regional and national authorities, engineers and consultants at different levels, among others'. And 'the material produced was widely disseminated in print, video, and placed on the project website'. The project led to 'the broad acceptance of RE technology among different institutional actors (Ministry of Energy, Ministry of Agriculture, among others) due to the proven results of the

[113] Communication from PPLC01.

projects', which 'fostered acceptance of RE technology as an alternative for the development of rural areas' – and, later, for the development of the utility-scale Wind and Solar sectors (Rodriguez, 2012, pp. 1–15).

The CNE/GIZ Collaboration (Wind and Solar)

The UNDP, however, was only one out of two foreign aid agencies whose efforts, in collaboration with those of the CNE, made a difference. The second was the German GIZ, then known as GTZ. From 2004 onward, this agency partnered with the CNE to develop and execute a series of capability-building projects that, unlike those that were done in partnership with the UNDP, had the specific goal of fostering the development of a utility-scale NCREs sector in the country. This was a very different goal from rural electrification, a goal that, instead of leading to an indirect contribution to the capabilities of the Wind and Solar sectors through the creation of positive externalities, involved the translation from an advanced to a lower-complexity country of a series of institutions that would come into direct interaction with entrepreneurial agents. The first of these capability-building projects was the *'Renewable Energy in Chile'* project, which ran from 2004 to 2010. This was followed by a series of other projects which, by 2016, were still ongoing.

The first two issues on which the CNE and the GIZ focused their joint efforts was the promotion of entrepreneurship and the updating of regulations. The contribution of the partnership to the first of these issues was reflected in a number of NCRE project management guides and similar documents which they co-wrote and then made publicly available (MINENERGIA/GIZ, 2012a, 2009, 2007a, 2007b). These documents contained valuable information about the nuts and bolts of becoming involved in sectors which were new for domestic private actors. On this matter, the collaboration also released a software tool[114] for the analysis of the profitability of renewable energy investments (GIZ, 2015), which was also made available for free.

With regards to the contribution of the partnership to regulatory updating, the GIZ website was by 2009 claiming that 'regulations governing renewables were prepared with project support and became effective at the beginning of 2006', tackling issues such as 'grid access for power plants of up to 20 MW capacity and their integration into the energy market' and the availability of 'technical standards for grid connection'. All of this, they claimed, improved 'the economic and legal conditions for RE projects' and facilitated 'entry into the market for new actors and investors[115]'. In sum, what took place in this area was a

[114] Available at http://www.4echile.cl/economic-calculation-tool/
[115] web.archive.org/web/20110131180358/http://www.gtz.de/en/themen/8956.htm

transfer of regulatory knowledge from the German context – where renewables were well established – to Chile – where they were a novelty.

The third clear contribution of the CNE/GIZ collaboration was the generation of a wealth of public knowledge about the techno-economic potential of the different NCRE technologies. By the middle of the 2000s, this was an area about which little public or private knowledge was available in Chile. Although there were scattered bits of data about the wind and solar conditions of the territory, which had been collected for various purposes by the government, some universities, and a few private sector actors, this data was sparse, not always adequate, and had not been systematised[116]. This was a significant drag for these two sectors, as lack of information about the technical potential for wind and solar generation and its geographical location played against the attraction of investors and made resource prospection more expensive. The CNE and the GIZ – which ran their own network of ten[117] solar and thirty-nine[118] wind prospection stations in the country – tackled these issues, collecting and systematising this information and making it freely available around the period these two sectors took off (MINENERGIA/GIZ, 2012b; Santana, 2014).

The Birth of ACERA (Wind and Solar)

At about the same time the CNE/GIZ partnership started in 2004, an organisation that became even more significant to the development of the regulatory environment of the renewables was created. This was the trade association ACERA, born from the initiative of about a dozen professionals, with the goal of fostering the development of the renewables in the country. As is usually the case with trade associations in HMEs (Schneider, 2013), the most important function of ACERA has been to lobby the government for the creation of a regulatory environment favourable to the renewables[119]. Indeed, one interviewee[120] reported that ACERA was instrumental in the establishment of the new energy auctioning process, which – as we saw in Chapter 4 – was a significant germination period driver for the Solar sector, and an important driver of the post take-off growth of the Wind sector.

---

[116] One of the books where the results of these efforts were published stated that: "el presente libro constituye un valioso aporte, ya que *por primera vez* [my italics] se levanta un diagnóstico completo sobre el potencial eólico, solar e hidráulico para generación de electricidad desde la Región de Arica y Parinacota hasta la Isla Grande de Chiloé, lo que apoyará decididamente al diseño de políticas públicas de fomento para las ERNC y a la orientación para inversionistas en general" (Santana, 2014, p. 6)

[117] 9 active and 1 non-active by 2014.

[118] 22 active and 17 non-active by 2014.

[119] Their mission statement, which can be found in www.acera.cl/acera/, is to 'promote a regulatory framework that allows Non-Conventional Renewable Energies compete on equal terms with conventional generation sources' (own translation). Also

[120] PPYM56

The reason why an intermediate able to articulate the interests of the sector and feed them into the governmental bureaucracies has been so important is that, despite the rhetoric about 'level playing fields' from both the conventional and the renewable generators, energy sector regulations in Chile – as in most places – are so complex that they inevitably favor some technologies over others. We have already seen how this was the case with the replacement of the old electricity auctioning process by a new one that included hourly blocks. But there was also a web of less important but more numerous regulations about matters such as impact mitigation, interconnection procedures, operation and maintenance rules, information disclosure, and various others that had been created when the energy sector did not have NCRE generators and thus did not take into account their specificities. Very often, this worked to their detriment, for in the absence of clear rules about these matters, developers and sponsors were vulnerable to delays and discretionary decisions by the regulator, adding uncertainty to their projects. ACERA was instrumental in changing all of this, and by many accounts[121] they have been very successful – particularly so since a resourceful professional with years of relevant experience, working among other things in the organization that operates the electricity network (whose doings are key to the success of the renewables), became its executive director in 2012.

The Rise of the Renewables in CORFO's Agenda (Wind and Solar)

The birth of ACERA coincided with the period when CORFO – the main designer and executer of industrial policies in Chile – took a strong interest in the development of the NCRE sector. The support of this key government body became noticeable from 2005 onward, when it established an internal program to back these technologies (the *Programa de Energias Renovables No Convencionales,* see Gomá, 2009). The real breakthrough, however, came when the organisation selected NCREs (along with biofuels and energy efficiency) as one of four transversal sectors whose support was deemed to be of strategic importance to economic development (which they did after a high-profile consultancy work done by the *Boston Consulting Group* identified it as such). This rise of the renewables in CORFO's agenda came at a good time. In these years, the government had recently established a not-inconsiderable mining royalty, and had ear-marked it for economic development goals. Indeed, the consultancy work which pointed to the NCREs as high-priority was in fact part of a broader process to plan how to spend the fresh funds that were coming to the fiscal arcs (Rivas, 2012).

[121] Communication from PPHR82, PPHW74, PPZL84, PPYM56.

The previous chapter showed how CORFO, as part of its support activities, fostered the entrepreneurial function through various undertakings aimed to attract foreign investors to the Wind and Solar sectors. The agency, moreover, supported the function by providing some financial support to project developers[122]. But CORFO was also a significant contributor to the development of sectoral capabilities. One of its biggest contributions in this respect was the creation, in 2009, of the *Centro de Energías Renovables*. As soon as it was created, this new and sizable task-group took to the collection, systematisation, and diffusion of all sorts of relevant information about the renewables, which was a function no one else had taken. And one other contribution of CORFO was the support it gave to the development of relevant skills through a) the funding of 'technology missions' in which businessmen would go abroad to visit projects, vendors, trade fairs, and anything that would help them to get better acquainted with a certain NCRE technology of their interest; and b) the provision, in partnership with the *Ministerio de Educación*, of scholarships for technicians to study abroad for short periods so that they could acquire the skills needed to build and operate NCRE power plants[123].

One more way in which CORFO helped strengthen the sectorial capabilities of the Wind and Solar (and the other NCRE) sectors was by supporting the development of a network of firms able to provide all sorts of ancillary services to the project developers and the project sponsors (services like due diligence, measurement and analysis, engineering support, calibration of equipment, logistics, repair and maintenance, among others). To this end, in 2009, the agency hired a consultant to identify the ancillary services that needed to be strengthened the most, and to devise and execute activities to attract foreign firms that could provide these (EVALUESERVE, 2009). The agency later engaged in similar actions to the same purpose, which were not necessarily focused on the attraction of foreign firms but also on the development of domestic expertise (Hentzschel and Flores, 2011)[124].

---

[122] Up until about 2011 CORFO ran two second-floor credit lines which benefited RE projects. These credit lines were later discontinued and replaced by a new financial aid program in which CORFO's support was materialized through the provision of guarantees that allowed investors in weak financial positions to seek private sector funding on better terms. In addition, CORFO ran a program of subsidies to the development stage of NCRE projects which developers could use to fund up to 50% of the cost of development studies and which by April 2009 had disbursed MM US$ 4.18 to support 133 NCRE projects of different technologies, including many wind and solar ones (CORFO, 2010). One interviewee explained that the goal of CORFO's financial support programs was not just to providing funding for projects or sectors or regions of national priority, but also to lure domestic and international finance providers into financing them.

[123] See www.tecnicos.mineduc.cl/index2.php?id_contenido=28451&id_portal=73&id_seccion=3994 and also cifes.gob.cl/blog/2015/09/entregaran-mas-de-500-becas-para-formar-tecnicos-instaladores-de-sistemas-solares-fotovoltaicos/

[124] It would, however, be an overstatement to attribute the development of the ancillary services sector too much to CORFO and too much to the foreign element: when they became aware that the

The Arrival of Highly Skilled Spanish Immigrants (Wind and Solar)

The last of the events that significantly strengthened the capabilities of the Wind and Solar sectors was the influx of highly skilled temporary and permanent immigrants, especially from Spain. As is well known, the economic turmoil caused by the 2008 recession brought severe worldwide waves of unemployment (Cho and Newhouse, 2013; Pissarides, 2013). Largely because of the natural resources boom, many Latin American countries were caught by the recession in a strong economic position and were able to withstand it reasonably well (Ocampo, 2010, 2009). This made them attractive migration destinations for unemployed foreigners. Many of these were Spaniards, for whom Latin America was attractive not just because of this but also because of the historical linguistic and cultural affinities.

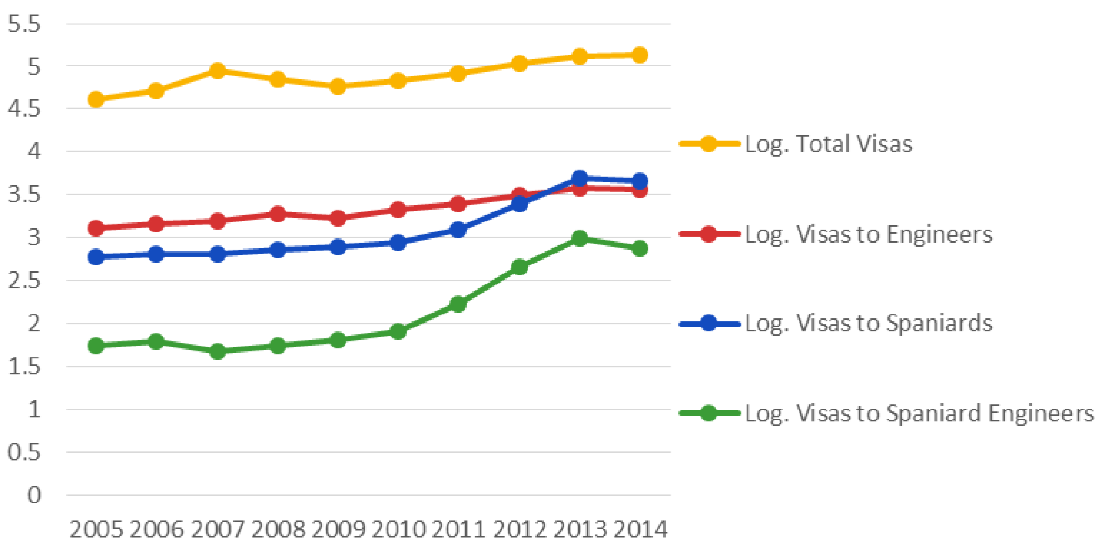

Figure 6.1: Visas granted by the state of Chile to foreigners, 2005-2014. *The y-axis shows the logarithm of the number of visas granted each year. The growth of the Total Visas curve by almost half a logarithmic point shows the massive increase in immigration to Chile in these years, which went from 41,985 visas in 2005 to 137,972 in 2014. The Spaniards and Spaniard Engineers curves coming closer together indicates an increase in the proportion of visas to Spaniards that went to engineers. Source: own elaboration based on immigration data acquired through a freedom of information request to the state of Chile.*

renewable energies were on the rise, many domestic service providers invested in the development of the capabilities that would allow them to provide these services. Such was the case of the crane rental firm that bought the first high-altitude cranes in the country to be able to help mounting aerogenerators (*Burger Gruas*); of the trading firm that developed a specialization in the import of renewable energy sector equipment (*Agencia de Aduanas Sesnish*); and of many others like these two.

As Figure 6.1 shows, Chile became one such attractive destination for immigrants in general – Visas doubled from 2008 to 2014 – and in particular for Spaniard ones: while the 772 Spaniards that asked for Visas in 2008 amounted to 1% of the yearly total, the 4,928 that did so in 2013 represented 3.7%. But the change in the composition of the set of immigrants was even more important than its growth: while only 7.5% of the 2008 Spanish Visa beneficiaries were engineers, those who claimed to be engineers in 2013 were a full 20.2% of the total. Thus, Spanish immigration did not just grow in absolute and relative size: it also became significantly more skilled.

Many of these Spanish immigrants had made careers in the rise of the NCRE sector in Spain, and found themselves to be in high demand in its emergent Chilean counterpart, which was full of Spanish firms: about 25% of the new subsidiary Wind developers, and 36% of the Solar ones, were from this country. Many of these firms, maybe most or even all[125], had Spaniards in their payrolls, Spaniards with skills which were not just high but also highly relevant.

The Creation of Red Biogas (AD)

At the sectorial level, i.e. leaving aside the constitution of developers and sponsors and their internal learning processes, the one event that significantly strengthened the capabilities of the AD sector was the establishment of a network – *Red Biogás* – with the aim of 'linking together the relevant actors which are directly or indirectly related to biogas as an energy source in Chile[126]'. The network became active in about 2009, and was run by a Chilean university that hosted a research group working on anaerobic digestion, and that was interested in promoting its diffusion (a group which, in fact, were the developers of one of the earliest AD projects).

For a few years after its establishment, the network strengthened the capabilities of the sector by organising events, hosting congresses, publishing information, and similar actions. Being based on a university, its hosts also ran a handful of short and at least one longer course about the topic. But the founding energy was soon exhausted: by 2014, the network seemed to have become inactive: by August 2016, the last post on their website was more than two years old. Perhaps because of its small size and the diversity of its market, the AD sector had much less of a sectoral identity, and sectorial institutions, than the Wind and Solar ones.

---

125 Certainly all of the ones that I interviewed.
126 www.redbiogas.cl (own translation)

6.2. Foreign Skills and Capabilities at the Firm Level

As Malerba and Nelson (2011, 2012) have shown, successful catch-up processes almost always rely on some form of access to foreign skills[127]. In this regard, the development of the Chilean Wind, Solar and AD sectors were no different: in all three of them, the capability of developers and sponsors to pursue the entrepreneurial opportunities, and in this way fulfil the entrepreneurial function, often hinged on their being able to access such skills. The participation of foreign 'human capital', however, may vary – and, as we'll see, *did* vary – from sector to sector, from firm to firm, from project to project, and from task to task. Our goals in this section are to characterise the scale and scope of the contribution that foreign skills made to the capabilities of the entrepreneurial agents, and to understand the reasons that made this contribution vary in the aforementioned dimensions.

6.2.1. Data and Methods

In order to gather data to explore these matters, I started by collecting documentation and conducting pilot fieldwork interviews to identify the main tasks that needed to be undertaken to complete the three kinds of projects. The results of this work are shown in the upper part of Figure 6.2. As shown there, for each of the sectors I identified twelve tasks, which I then organised into six task groups. The first task group is *project management*, which – as the name implies – consists in the coordination and supervision of the project activities during the development stage. The second task group are the *design tasks*. In the cases of Wind and Solar, these include resource prospection (location scouting, wind or solar radiation measurements, energy yield simulations) and the conceptual and basic engineering of the facilities (further technical feasibility studies, sizing of the plant, decision of which equipment to use, drawing of blueprints); in the case of AD, these include substrate studies (studies of the biomass that is to be utilized for the digester), the conceptual and detailed engineering[128], and the planning of the input procurement logistics (i.e. of when and how will the substrate make it to the plant and where will it go next, whom will transport it and how it will be carried, and other such matters). The third task group is *environmental management*, which consists of making sure the facility complies with socio-environmental regulations. The fourth are the *business model tasks*, which include the

[127] Foreigners may partake in projects from the distance – far easier now that we have computers and the Internet than it was in the past (Miozzo and Soete, 2001) – or as temporary or permanent migrants.

[128] In Wind and Solar sector projects, the detailed engineering – calculations of amount of materials to use and other such civil works matters – are usually left to the construction contractor, hence the separation of engineering in three phases rather than in the two used for the case of AD.

design of a viable business model for the project, the evaluation of its expected costs and incomes, and the negotiation of whatever financial arrangements need to be agreed upon to finance its construction and operation. The fifth are the *construction tasks*, which for Wind and Solar include the detailed engineering, and for all three cases include the organisation, management and supervision of the activities of the construction site, and the commissioning of the facilities. The sixth and final group are the *operation tasks*, which include monitoring, operating, repairing and maintaining the facility.

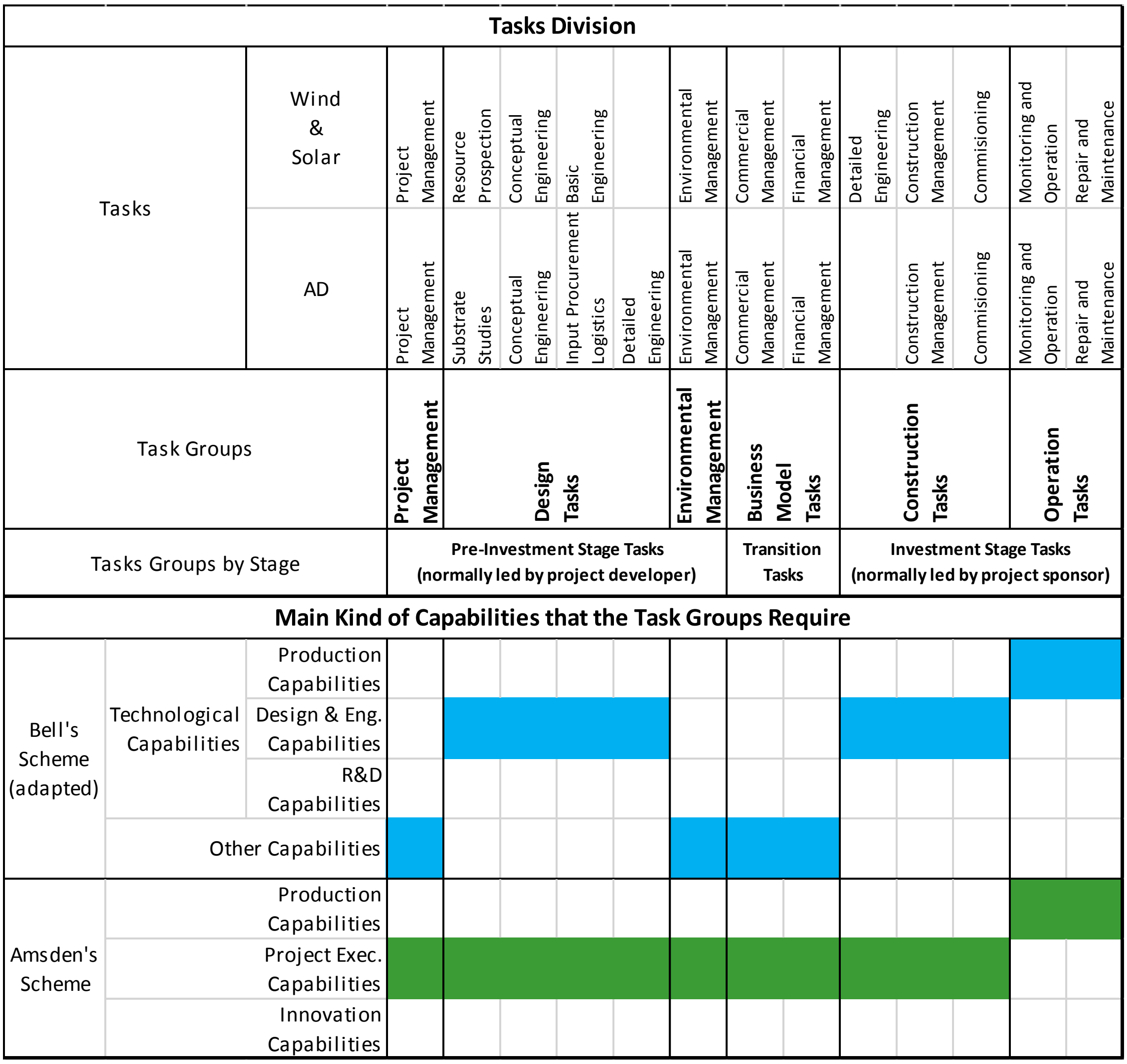

Figure 6.2: Tasks, task groups, and capability requirements. *The blue bars indicate the main type of capabilities required by each task group according to the classificatory scheme adapted from (Bell, 2007), and the green bars to the scheme used in (Amsden, 2001).*

The lower part of Figure 6.2 shows an ad-hoc characterization of the main kind of capabilities that each of these six task groups required. The characterization was done by me based on the classificatory schemes found in (Bell, 2007) and (Amsden, 2001) (which were detailed in Chapter 3), and on descriptions of the tasks by interviewees and found in secondary documents (e.g. Rosende, 2010). In the case of Bell's adapted scheme, the operation tasks require production capabilities, and the design and construction tasks require design and engineering capabilities; no task actually requires R&D capabilities, for in all cases the facilities were based on well-known methods and technologies; the management of the project, the environmental management, and the business model tasks, all are of a more managerial than engineering nature, and thus require the kind of capabilities that don't fit so well with the label 'technological'. In the case of Amsden's scheme, the operation tasks require production capabilities and all other tasks require project execution capabilities; here, again, no task requires the more advanced innovation capabilities, for the same reason they don't require what Bell calls R&D capabilities.

With this task division at hand, I then designed a questionnaire to ask managers and engineers about the degree to which foreign skills were relied upon to complete each of the twelve tasks in the projects that they were involved in. The questionnaire asked the interviewee to state whether each of the twelve tasks was undertaken by a team composed of *a) practically no national professionals, b) some national professionals,* or *c) a majority of national professionals*. Ideally, the questionnaire would have been applied to get information about the full universe of 22 Wind, 41 Solar, and 51 AD facilities that had been completed or were under construction by the end of 2016. However, time and resource constraints, and limited access to interviewees made this impossible. Hence, I was able to get data about only 13 Wind, 12 Solar, and 4 AD sector facilities. In the cases of the Wind and Solar sectors, the sample was not small in relation to the universe, and was reasonably diverse in a number of dimensions that – as we will see below – are of interest to us: size, timing, and kind of developer. In the case of the AD sector, the sample is far smaller in relation to the whole population, and is not diverse in terms of size (it only includes relatively large and electricity-generating anaerobic digesters), timing (it includes only late facilities), or kind of developer (it includes only facilities developed by domestic diversifiers or new domestic firms). However, the AD sample *is* representative of a subset of these kinds of facilities that is especially interesting because of the much higher complexity of its members: the seven facilities that included grid-connected electricity generation components. Thus, in this last case, the data are not representative of the whole of the AD sector, but they do provide a somewhat more representative view of the set of facilities that demanded the most advanced capabilities.

6.2.2. The Foreign Skills Content Indicators

Once I had gathered these data, I used it to create, for each project, a set of indicators of the degree to which foreign skills had been tapped into to complete the tasks on the different task groups. To construct these foreign skills content indicators (FSCIs), I first assigned responses a value of 1 when interviewees affirmed that practically no national professionals had been on the team that undertook a given task in a particular project, 0.5 when there had been some of them, and 0 when the team had been fully composed of nationals. For task groups with just one task, the value of the indicator was simply calculated as the value assigned to the response. For task groups with several tasks, the value of the indicator was calculated as the average of the response values of the tasks that composed it. The results can be seen in Figure 6.3, which provides a succinct overview of the degree to which foreign skills and the kind of foreign skills that went into the projects of each sector.

There are several features of interest in the radio graphs of this figure. The first thing to note is that there was considerable variation in the kind of foreign skills that went into the different projects, and also on the degree to which they did so. Two facilities – *Ucuquer I* in Wind and *Salvador RTS* in Solar – did not rely on foreign skills at all. A few others, like the solar project *Laberinto* and three of the four AD projects, tapped into foreign skills only for tasks that required design and engineering capabilities. And many other projects had foreigners work to different degrees in tasks that required both technological and non-technological capabilities. There was, in short, no easily recognisable sectoral pattern: things were different from project to project and even from task to task.

There were, however, some noticeable regularities. By way of example, several projects – *Canela 1, Cristoro I, Ucuquer I, San Pedro, Salvador RTS, Laberinto, Romero Solar, L&E Purranque, Tamm* and *Las Pampas* – did not rely at all on the skills of foreigners for tasks requiring non-technological capabilities (project management, environmental management, and business model tasks). But projects that did not tap into foreign skills for tasks requiring technological capabilities (the design tasks, the construction tasks, and the operation tasks) were exceptional: in fact, there were only two, the two that were fully domestic. Also, only a few facilities tapped into the skills of foreigners to project-manage the development stage, while no facilities relied on foreign skills for the environmental management task.

There was, finally, an interesting timing regularity in the case of the Wind sector: in this case, the foreign skills content of earlier projects was smaller than that of later ones, which is puzzling if one reasons that the earlier stage of the development of a new sector is the time when the skills of foreigners ought to be needed the most.

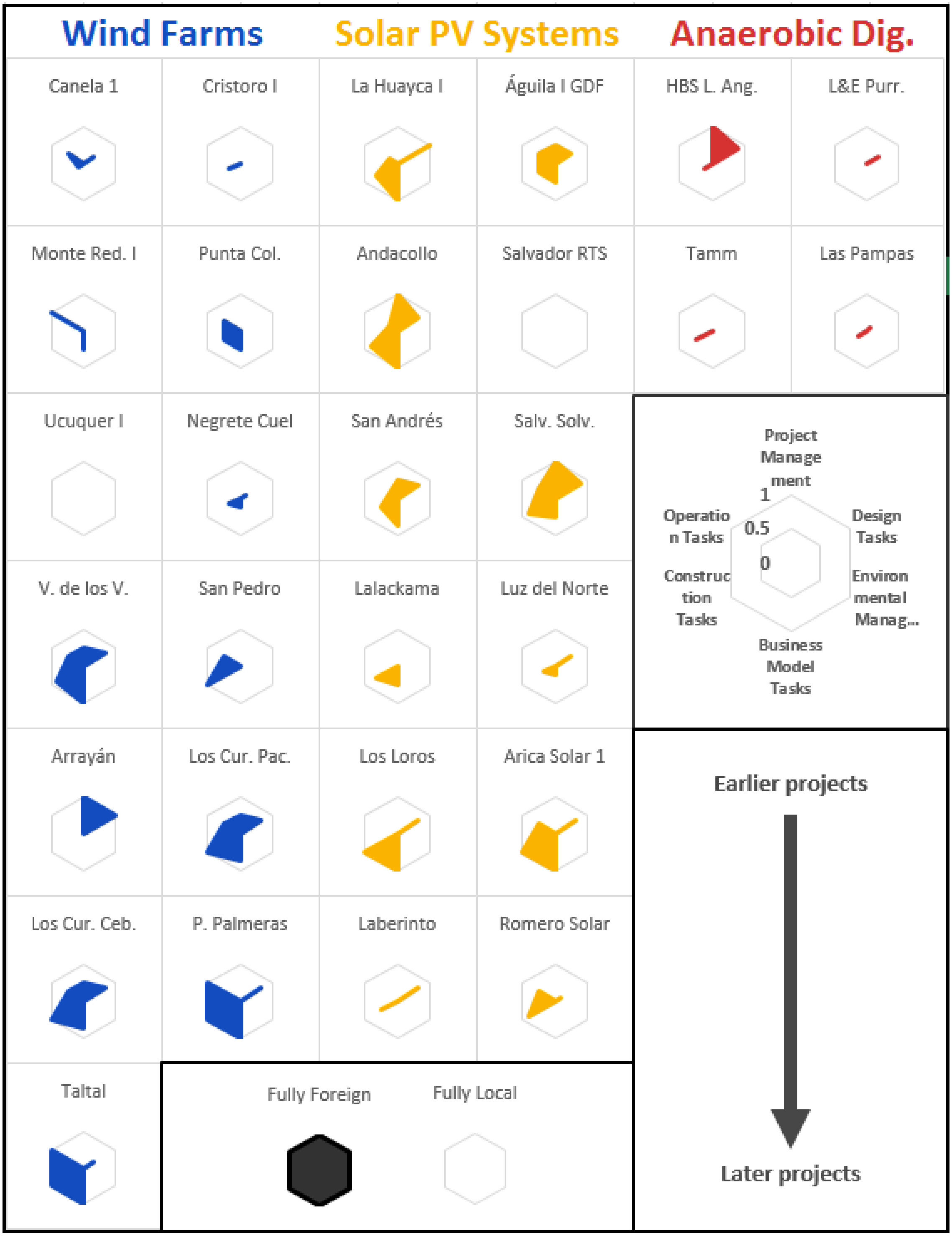

Figure 6.3: Foreign skills content indicators for a sample Wind, Solar and AD projects. *The radio graphs represent the six groups of tasks that needed to be completed to finish each project. Earlier projects are at the top, latter projects at the bottom. Source: own elaboration based on interviewee responses to project questionnaires.*

There were, therefore, some visible patterns in the data. And there may, of course, be more which are not so easily visible. But what explains them? One may approach this question by looking at differences in the task groups, and by looking at differences in the projects. We will do both, starting with the first approach.

6.2.3. Task Traits and Foreign Skills Content

There are several dimensions in which tasks can differ from one another, and these differences may in some cases be linked to differences in the degree to which foreign skills are relied upon to complete them. One of these dimensions, as we'll see below, is the 'novelty' of the tasks; and another is their 'tradability' – if one may call it like that. In what comes next, we will better define these two dimensions, and explore whether they had anything to do with the differences in the foreign skills content of the different task groups.

Novelty

The completion of tasks requiring skills which are uncommon in an economic system stands, for obvious reasons, to benefit more from foreign skills infusions than the completion of tasks requiring more widely available skills. The former kinds of tasks, moreover, will arguably be perceived as more 'novel' than the latter. Thus, one may expect tasks which are perceived as more 'novel' to make more intensive use of foreign skills than those that are perceived as less novel. We may call this the 'novelty' hypothesis.

To gather data to probe this hypothesis, I first showed interviewees from all three sectors the tasks in which I had divided the respective projects, making sure they understood what each of them involved. Then, I asked each of them to select the tasks that 'because of their novelty, were the most challenging to complete when the first of the sector's projects were being undertaken' (the original question was in Spanish). Interviewees could select as many tasks as they wished, and on average they selected slightly over two. Having their selections, I then turned them into numerical values: tasks which were not selected were assigned a value of zero; and tasks which were chosen were assigned a value of one divided by the total number of selected tasks, so that the sum of the scores of all selected tasks was equal to one (this in order to normalize for the number of tasks that each interviewee selected, so that the opinions of those who selected more than one task did not count more). Once I had turned each interviewee's responses into such vectors of twelve numbers (one number for each task), I grouped and added the values of the tasks in the six different tasks groups, and then divided the six resultant values by the number of tasks within each group (this to normalize for task group composition, so that task groups with more tasks did not get more representation because of that). Having, as a result, a collection of vectors of six numbers, each representing an interviewee's normalised opinion about the 'novelty' of the different task groups, I then added the vectors for all interviewees within each sector. The values of the three resultant vectors (one for each sector), once normalised so that they added to 100, represent the adjusted percentage of mentions for 'novelty' that each task group got. For each sector, I then scatter plotted and regressed these vectors against the average FSCIs of each task group, so as to find out whether there was any correlation between the two sets. Figure 6.4 shows the results.

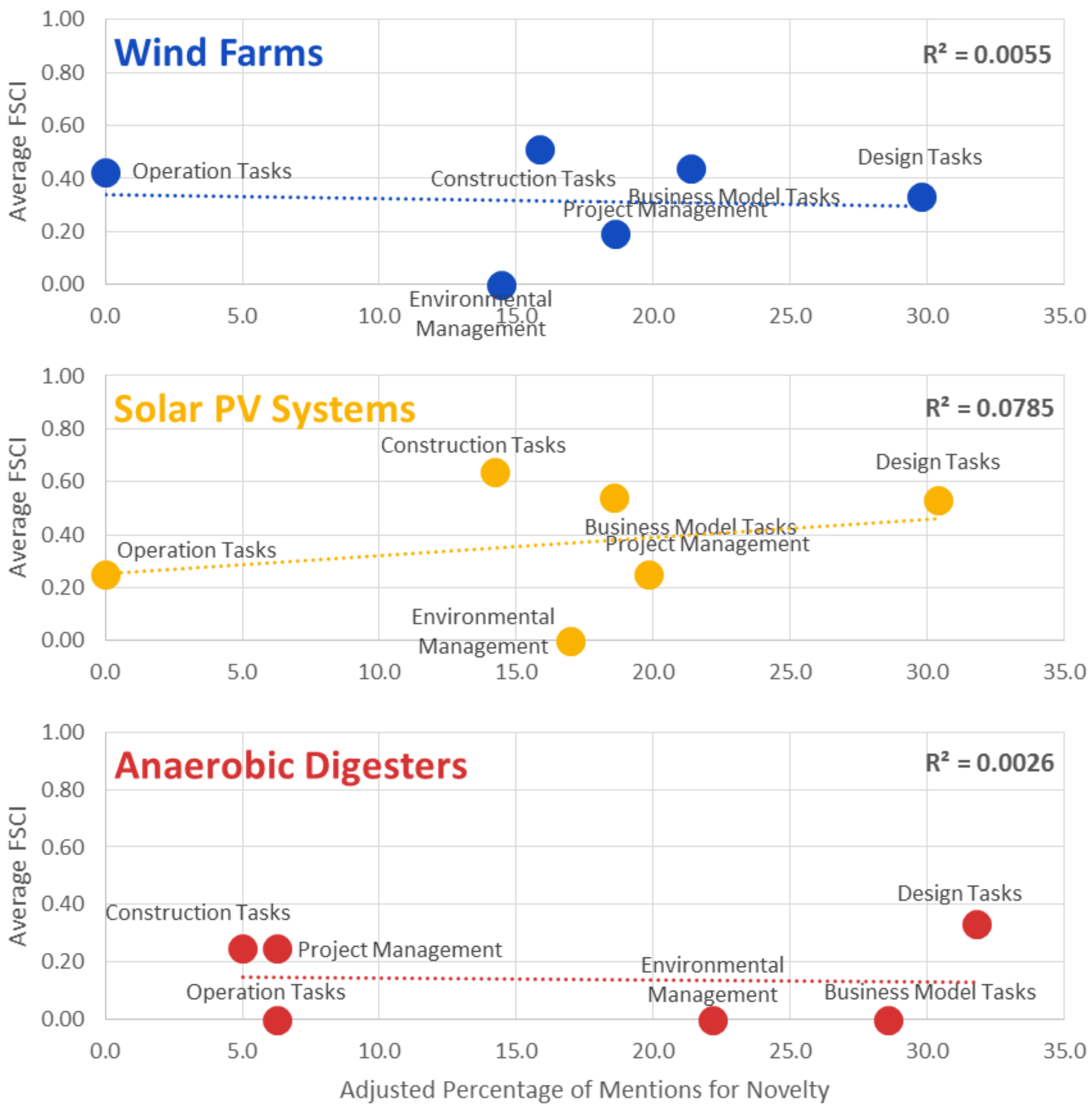

Figure 6.4: Foreign skills content indicators and perceived task group novelty. *Task groups perceived as more 'novel' (relative to other groups, not in any absolute sense) are to the right. To get the data, interviewees were asked to select the tasks that 'because of their novelty, were the most challenging to complete when the first of the sector's projects were being undertaken'.*

The results show that, contrary to what one may expect, there was no systematically significant correlation among the perceived 'novelty' of the task groups and their foreign skills content. Although there was some correlation in the case of Solar, this was not high. And in the cases of Wind and AD, there was practically no correlation. It was, therefore, not the case that foreigners were consistently more involved in the most novel tasks of the projects.

Some reflection informed by interview notes can help to clarify this seemingly counterintuitive result. Two of the task groups which were perceived as less novel, namely the construction tasks and the operation tasks, involved handling normally expensive imported capital goods. These tasks were not perceived as very novel, and thus domestic agents would not have required a great deal of capability development efforts to be able to undertake them. Some interviewees[129], however, reported that these capital goods were provided in the form of what Davies and others have called 'integrated solutions', i.e. capital goods that come tied with insurance, guarantee, and service contracts (Davies et al., 2007; Davies and Brady, 2006). As one would expect, such contracts often required that the associated services be provided by the capital goods manufacturer, all of which were foreign firms. Guarantees and insurances would often not be valid if this was not the case, making it costly and risky just to buy the hardware systems and nothing else, if this option was even provided.

The above argument does not, however, apply to the other task groups, which do not involve handling expensive hardware systems. What, then, is one to make of the seeming unimportance of their perceived novelty in the degree to which foreign skills were relied upon to complete them? As we'll see next, a significant part of the explanation has to do with how easy it is to leave tasks to people and organisations that do not have a permanent presence in the economy or that have not been around long enough to develop a more than superficial knowledge of the local milieu.

[129] PPYY55, PPHQ93.

Tradability

As we've seen (Figure 6.3), the environmental management of projects – not the most novel of the tasks, but also not among the least – was unfailingly undertaken by teams composed fully by nationals. What this task mainly involved was securing the government's permission to build the facility. This entailed making sure the project was designed in a way which would comply with complex bodies of regulation; undertaking environmental impact studies and, from these, making the case that the impact of the project was within what the law permitted and that the project included measures to mitigate impacts deemed unavoidable; and negotiating modifications to the project when the regulator was not willing to grant approval. These were all activities that required a thorough knowledge of the relevant regulations, benefitting enormously from acquaintance with the environmental impact evaluation system, and from localised knowledge about the project context. Arguably, these factors made this a task which was very hard to 'trade' (Lanz et al., 2011), i.e. to outsource to people or organisations without a permanent presence in the economy or which had arrived only recently. But was the 'tradability' of the tasks a factor that systematically influenced the general pattern of foreign skills content?

In order to probe this 'tradability' hypothesis, I followed a data collection and analysis procedure which was analogous to the one I followed to test the 'novelty' hypothesis of the previous section. This time, what I asked interviewees was to select those tasks that 'because of their nature, were the hardest to leave to foreign firms' (the original question was in Spanish), making sure they understood that by 'foreign firm' I meant those not yet established in the country or only recently arrived. With this, I constructed an (admittedly coarse) vector of indicators of the average perceived 'tradability' (in the sense explained above) of the different task groups, in the same way I did for their 'novelty'. A scatter plot and regression of these indicators against the FSCIs of the task groups is shown in Figure 6.5.

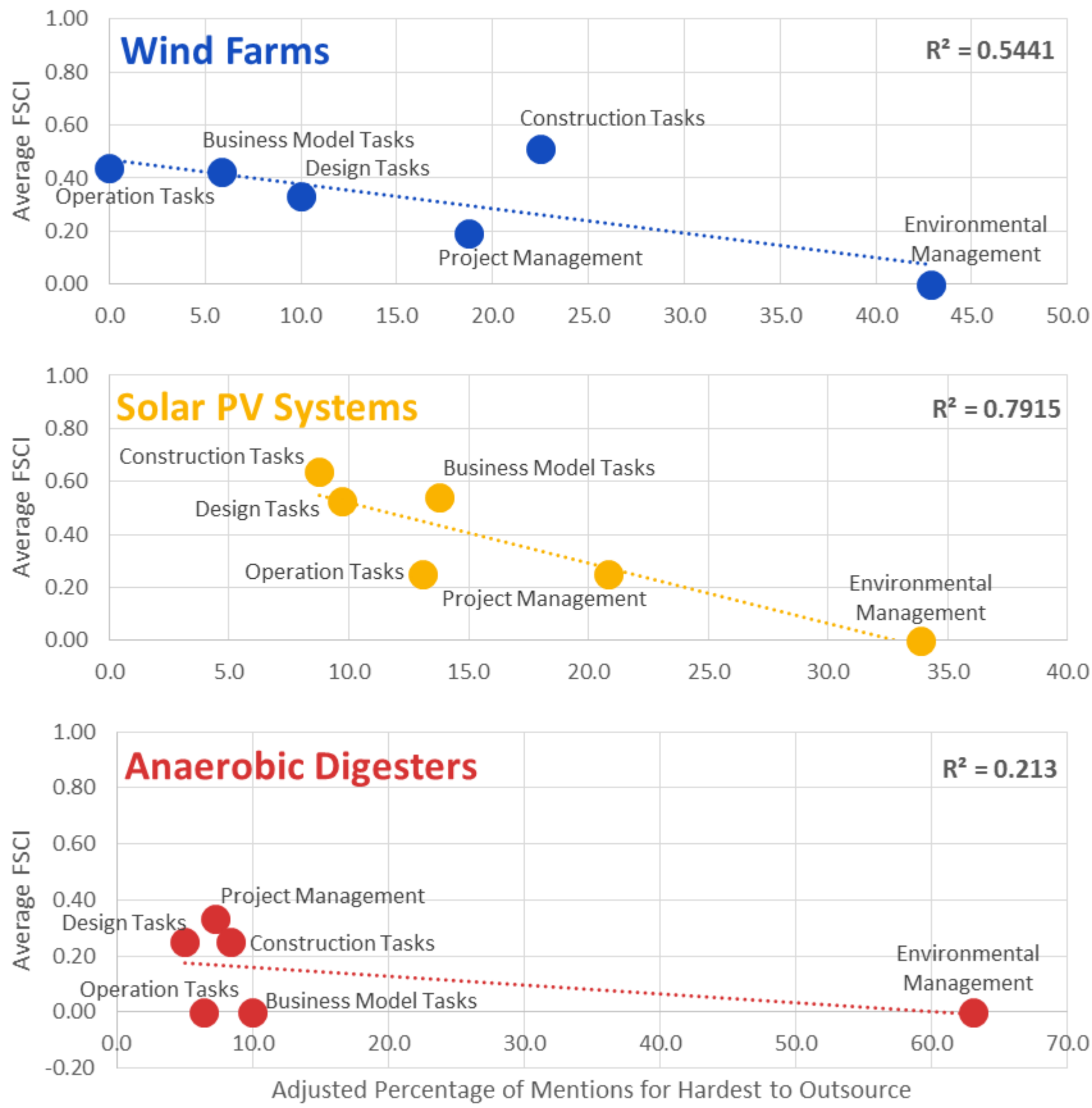

Figure 6.5: Foreign skills content indicators and perceived task group tradability. *Task groups perceived as less 'tradable' (relative to other groups, not in any absolute sense) are to the right. To get the data, interviewees were asked to select the tasks that 'because of their nature, were the hardest to leave to foreign firms'.*

The results show that, unlike their novelty, the tradability of the different task groups was strongly correlated with the degree to which foreign skills went into their completion. Foreign skills, in short, did – as one may expect – tend to go more into the tasks groups for which a lack of first-hand experience in the local economy was not perceived to be as significant a handicap.

6.2.4. Project Attributes and Foreign Skills Content

So far, the inquiry has focused on whether certain traits of the task groups relate to their foreign skills content. However, it is also possible for *project* rather than *task* attributes to affect the degree to which the skills of foreigners are tapped into. In this section, we will look at whether three such project attributes were significant in this regard: the kind of firm – domestic, semi-domestic or foreign – which undertook the tasks; the size of the projects; and their timing. For reasons that will be spelt out below, each of these three project attributes may be expected to influence their foreign skills content.

The analysis, in this case, will centre on the design tasks only, this for several reasons that make this a group of particular interest. The design tasks, to begin with, are one of the two task groups whose undertaking primarily required design and engineering capabilities (Figure 6.2). As Bell argues in (Bell, 2007), and as many have shown in empirical studies (Amsden, 2001; Cimoli et al., 2009; Hobday, 1995; Kim, 1997), it is by fostering the development of these particular kinds of capabilities that countries have been able to close the technology gap (Fagerberg, 1987) with the advanced economies. Therefore, it is important, for catch-up policy making, to understand the reasons why a sector's design and engineering capabilities may come to depend more or less on being able to access foreign skills. The design tasks, moreover, were perceived as the most novel task group in all three cases, meaning their mastering demanded the biggest capability development efforts from the local people and the domestic organisations. But, at the same time, this task group was perceived as one of the easiest to 'trade', i.e. to leave to people and organisations without a permanent presence in the country or with little previous domestic experience. The design tasks, therefore, were the task group that was most relevant to what Amsden has called 'the make or buy decision' (Amsden, 2001), i.e. to the decision of whether to become dependent on foreign economies to provide technological capabilities, or to develop these within the domestic economy. These are, in short, the capabilities that Bell is referring to when he writes that 'firms [can] use successive technologies that [are] increasingly advanced and productive, without increasing their own capabilities to create or change what they [use]' (Bell, 2009), and for this they are particularly relevant.

Developer Origin

The design tasks take place in the development stage of projects. Therefore, they are primarily undertaken, or at least coordinated and overseen, by the project developers. For several reasons, one may expect foreign developers to be more prone than domestic ones to tap into the skills of foreigners to complete these tasks. These developers, to start with, will usually have strong ties to their parent firms. This makes it easier for them to outsource tasks that their local staff is not capable of undertaking to these parent firms, or to ask them to send people to work on projects on a temporary basis. To the detriment of the local economy, these developers, moreover, may not be interested in developing domestic capabilities by training local people and forming local linkages so as to become more independent of their parent firms, for they may – often correctly – perceive that the capability development investments required by this would eat too much into their profits. This well known fact often puts foreign MNE subsidiaries at odds with the development agendas of catching-up country policy makers, and is the reason why much FDI and development research is about how to devise effective policies to encourage subsidiaries of MNEs to upgrade their local technological capabilities (e.g. Hobday and Rush, 2007) and to form stronger links with the domestic economy (e.g. Kelegama and Foley, 1999).

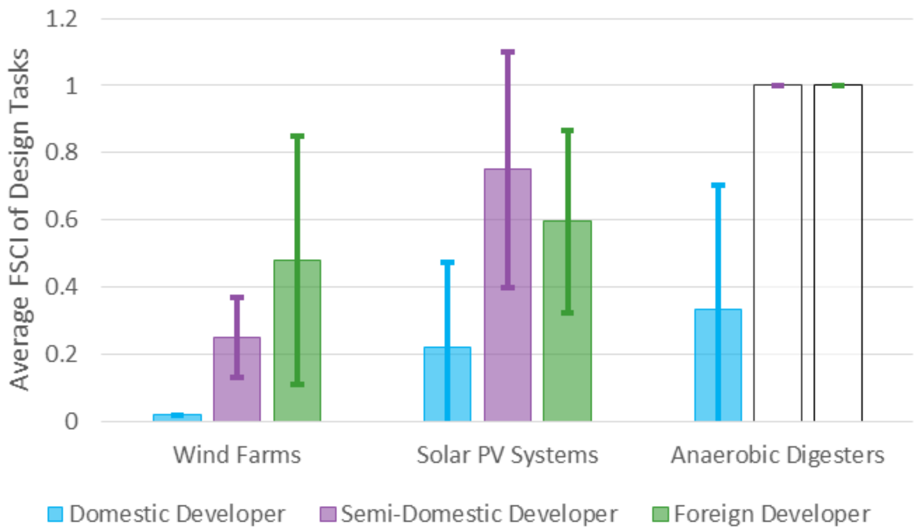

Figure 6.6: Average FSCI of the design tasks by kind of developer. *The bars show the average FSCI of this task group for all projects in the respective samples. The error bars indicate the standard deviation. No anaerobic digesters were developed by semi-domestic or foreign firms.*

Figure 6.6 shows the average FSCI of the design tasks for the different kinds of developers. As one can see there, foreign and semi-foreign developers from the Wind and Solar sectors were, indeed, more prone to rely on foreign skills than their domestic counterparts[130]. The high standard deviation of most of the averages, however, indicates

[130] In the case of the AD sector, we cannot make the comparison, for there were no foreign or semi-foreign developers. The average FSCI of the domestic developers is shown for reference.

that there was substantial variation from one firm to another. The tendency was thus only mild, and if an econometrical analysis were to be viable – the small size of the samples makes this unfeasible – it would probably show a statistically significant but low correlation among the two variables. In sum, the kind of developer did seem to influence the foreign skills content of the design tasks, but it was by no means its only determinant.

Project Size

One more variable that may be expected to influence the degree of foreign skills content of the design tasks is the size of a project. The line of reasoning that justifies this hypothesis is as follows. Sponsors, one may conjecture, will feel unsure about the technical soundness of projects designed by local people, this because – since the sectors are relatively new to the country – the locals may not have had much previous experience to hone their skills. Sponsors, moreover, may be unable to make judgements about the skills of the locals (which is what usually happens when they are investment firms without much of their own technological capabilities, or when they are diversifiers with technological capabilities in other areas) adding to their conjectured lack of trust in them. But, at the same time, one may expect that hiring locals to undertake the design tasks will be cheaper and maybe even faster than finding a way to gain access to what may be more costly and less accessible foreign skills. Thus, in sum, one may expect sponsors to deem local skills cheaper but less trustworthy, and foreign skills more expensive but more trustworthy. If this is correct, deciding whether to hire locals or foreigners to undertake the design tasks is a trade-off among price and trustworthiness. Since the development stage costs of projects – the stage when the design tasks are undertaken – are arguably less sensitive to projects' size than the investment stage costs[131], the higher investment in foreign skills may only be justified for the larger projects. And because failed designs bring greater losses when projects are bigger, trustworthiness may be particularly valued for the larger among them. Thus, one may conjecture that larger projects will tend to have higher foreign skills content.

However, the evidence that I was able to collect with regards to this conjecture is at best inconclusive and at worst contrary to it. Although, for the cases of Wind and AD, the correlation is present and goes in the right direction, for the case of Solar it is almost insignificant and, moreover, goes in the wrong direction (Figure 6.7). In addition, in the case of the Wind sector, smaller projects tended to be developed by domestic or semi-domestic

---

131 This because measuring the wind or the sun or the biogas-generating potential of a substrate, undertaking environmental impact studies, securing permits, and other development stage activities for a project of size X is not much cheaper than for a project of size 2X.

firms, and larger ones by new subsidiaries; given the small size of the sample, this makes it difficult to isolate the developer-origin effect described in the previous section from the hypothetical project-size effect that we are probing on this one. And, in the case of the AD sector, the size of the sample is just too small to trust the correlation. Thus, there are no grounds to argue that larger projects made more intensive use of foreign skills. This negative result is in line with the results of Hobday and Rush's study on Thailand's electronics sector (2007), where they show that the size of manufacturing plants of MNEs did not have an effect on their degree of development local technological capabilities.

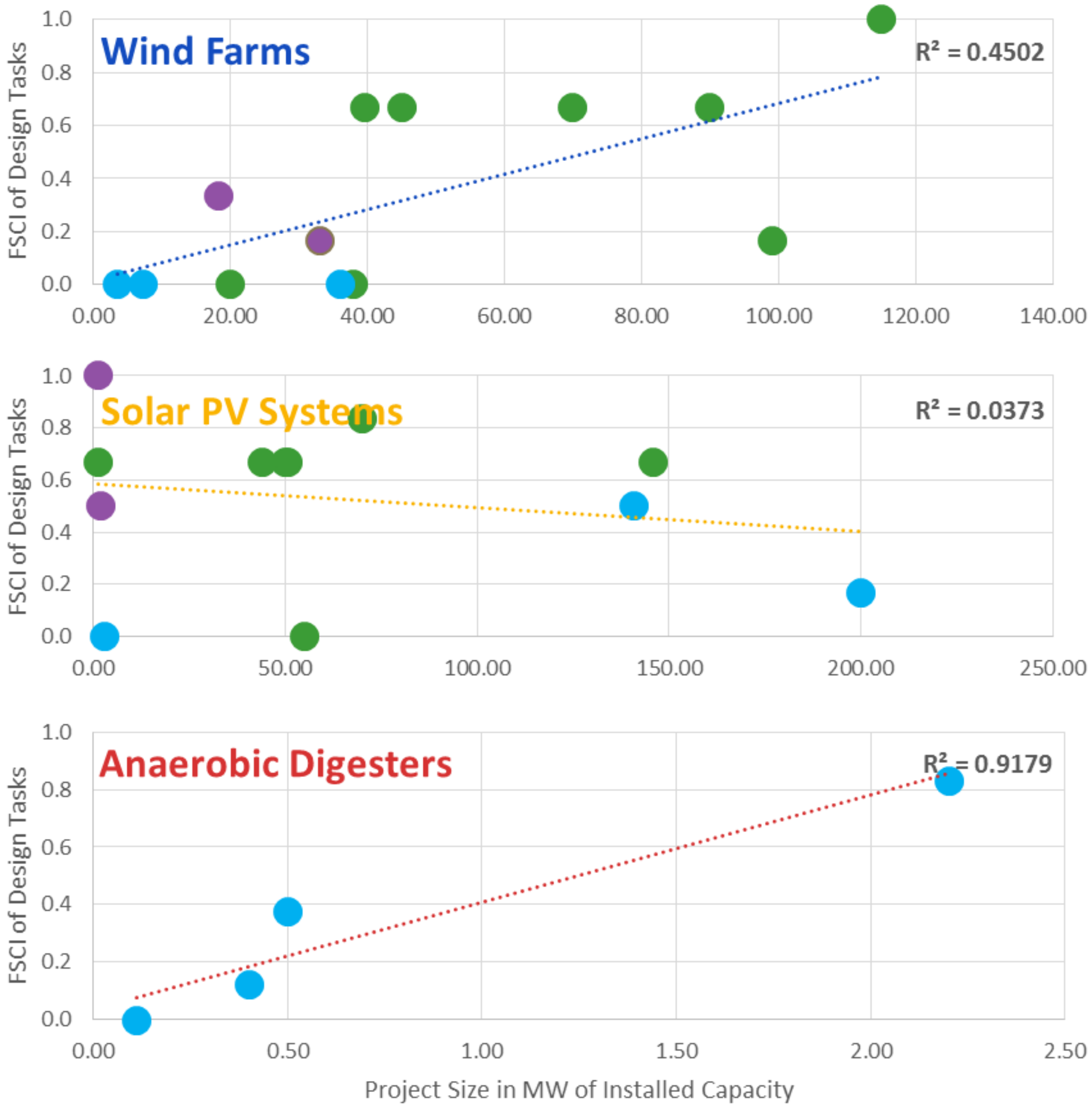

Figure 6.7: Foreign skills content of the design tasks and project size. *Each of the spheres is a project. The colour of the spheres indicates the kind of developer of each project according to the colour scheme of the previous figure: light blue for domestic, purple for semi-domestic, and green for foreign developers.*

Project Timing

A third attribute of projects that may be related to their degree of foreign skills content in the design tasks is their timing. Earlier projects, one may conjecture, will tend to have higher degrees of foreign skills content, this because, in the initial years of a sector's development, local people that have had the chance to acquire the skills that would enable them to partake in the completion of these tasks will simply not be available. Developers, both the foreign and the domestic, will simply have no choice but to rely on foreigners for these relatively novel (Figure 6.4) tasks. However, as time goes by, local people will learn the new skills, and the developers of later projects will then be able to trust them with the design tasks that they were initially unprepared to carry out.

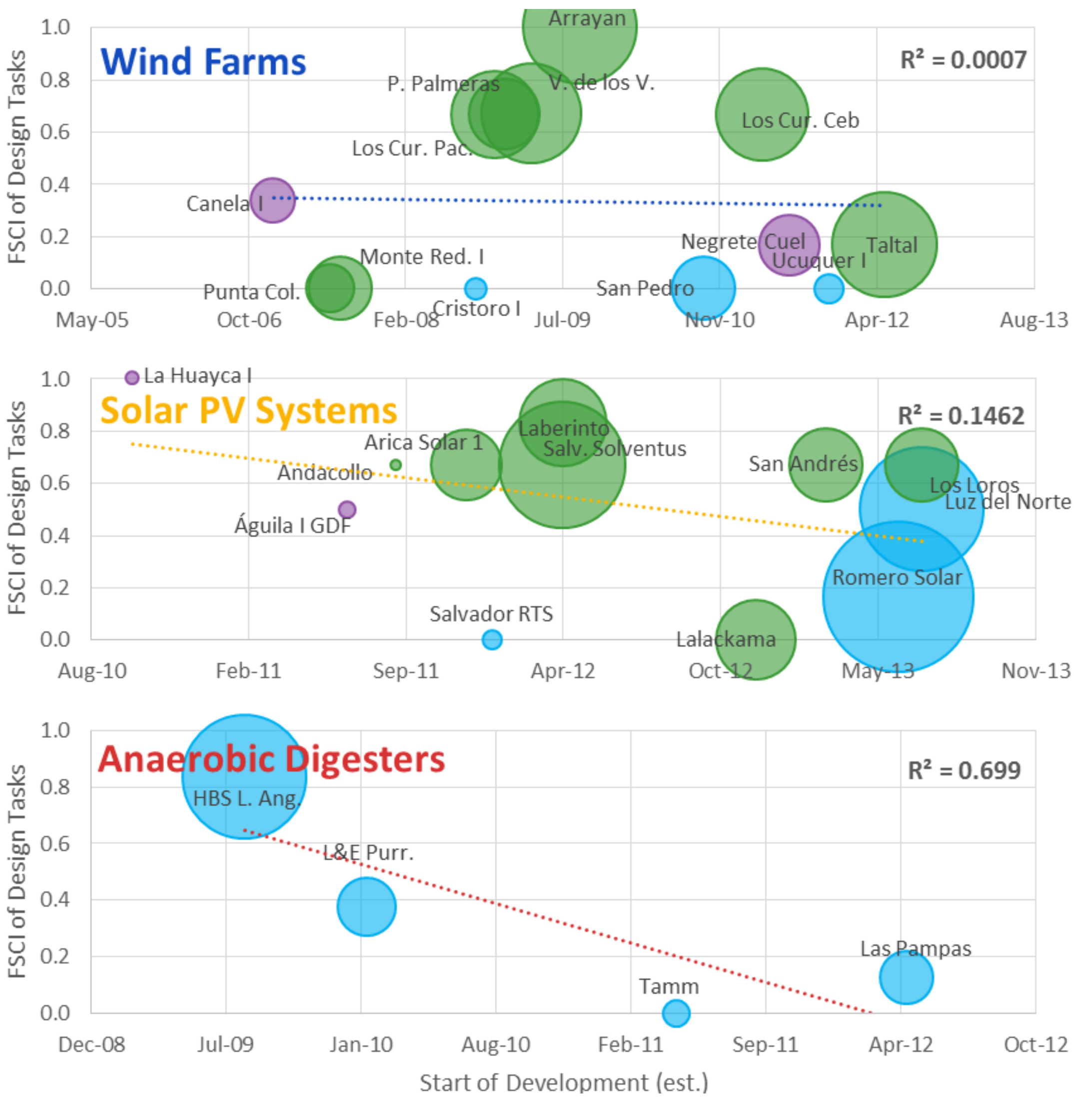

Figure 6.8: Foreign skills content of the design tasks and project timing. *Each of the spheres is a project. The areas of spheres are proportional to the size of the projects (for each sector, not between sectors). The colour of the spheres indicates the kind of developer (as in prev. figures).*

As one can see in Figure 6.8, the FSCI of the projects did tend to become smaller over time. However, in the case of Wind, the decrease was almost imperceptible, and the correlation coefficient negligible. And although the magnitude of the decrease and the correlation coefficient were both high for anaerobic digesters, the small size of the sample, in this case, means what it shows cannot be taken at face value. Thus, although the data is in line with the timing-learning hypothesis, it is far from conclusive.

6.2.5. An In-Depth Look at a Selection of Firms

Though the previous sections do provide some insights into the reasons why the scale and scope of the contribution of foreign skills varied among the projects, they also show that this was a complex matter that does not accept simple single-cause answers. Although three of the five hypothetical causal relations that we assessed – the one about the 'tradability' of the tasks, the one about the origin of the developer, and the one about the timing of the projects – were supported by the evidence, this support was strong in only one of the cases (the 'tradability' hypothesis). And even if the three hypotheses were right, they would only explain part of the results, for in all three cases there were several outliers: tasks which, though not easily 'tradable', had significant foreign skills content (e.g. construction tasks in Wind); tasks which, though undertaken by a new subsidiary, had very low content of foreign skills (e.g. design tasks in the *Lalackama* project); and projects which, though they came relatively late, tapped into the skills of foreigners to a significant extent (e.g. design tasks in the *Los Loros* project).

Clearly, there were more factors at play. In this respect, the results are in line with at least three studies that tackle a different but related question. The first are two studies by Marin and Bell, whom, in their research on foreign multinationals in Argentina, found substantial variation in the degree to which these MNEs developed domestic capabilities and links with the rest of the economy (Marin and Bell, 2010, 2006). And the third is the already mentioned one by Hobday and Rush, who arrive at a similar result in their study on Thailand (Hobday and Rush, 2007). In all three cases, the authors show that one of the main determinants of the degree to which MNEs develop local capabilities is their business strategy. In other words, it is common for subsidiaries in the same country, and even the same sector, to differ from one another in this respect. Put another way, these studies show that it is not just country-level or sectoral-level factors that determine the degree to which MNEs develop local capabilities: firm-level heterogeneity also matters (Nelson, 1991).

In line with the above studies, firm specificities are likely to have influenced the degree to which the entrepreneurial agents of the three sectors under study tapped into the skills of foreigners. Because of this, looking in some more qualitative depth at a selection of firms and their projects, in search for further clues about what led them to rely more or less on foreign skills, is a potentially interesting way to complement the more quantitative analyses undertaken above.

However, there are additional reasons to make this a promising complementary analysis. The inquiry above, note, was devoid of normative content: with the data that we looked at, it's hard to make judgements about whether the high or low degree of foreign skills that went into this or that task or project was positive or negative from an economic development perspective. By itself, a high foreign skills content is neither good or bad: it could, say, indicate projects are being developed and sponsored by new subsidiaries that are not developing links with the domestic economy, i.e. that are functioning as enclaves that do not generate knowledge spillovers (Nieto and Quevedo, 2005); but it could also indicate projects are being made possible by the availability of these foreign skills, i.e. that they rely heavily on these skills and the sectors would not be developing as much if these were unavailable. Besides providing further insights about why different projects had different foreign skills contents, a second and equally important reason to look in depth at a selection of firms is that this can help understand whether their reliance on foreign skills was good or bad from an economic development perspective. Thus, the last part of this chapter is devoted to this undertaking. The accounts that follow are largely based on interview notes with people from each of these firms.

The Case of Cristalerías Toro

Cristalerías Toro is a firm whose core business is glass manufacturing. By the time the Wind sector was about to take off, the company owned one manufacturing plant, a glass production facility with modern machinery that – because of the nature of the glass production process – used high amounts of electricity. This justified their having their own small electrical engineering department within their organisational structure, and their owning and operating their own small electrical substation. The firm was the main concern of a family holding which, before they entered the Wind sector, also ran a mining business, and which – in addition to this and the glass manufacturing ventures – nowadays runs two more businesses: a wind farm and the publication of an environmental magazine.

Cristalerías Toro entered the Wind sector as the developers and sponsors of the *Cristoro Wind Farm* – the only renewable energy project they've so far engaged on –, a relatively small facility (Figure 6.7) that they managed to complete with an almost insignificant degree of foreign skills content (Figure 6.3). Foreigners, in fact, were involved only in one of the construction tasks: the commissioning of the plant, which was largely left to the aerogenerators manufacturer – as it was common practice in a sector where the business model of most technology manufacturers was to offer integrated solutions rather than mere capital goods (Davies and Brady, 2006).

Cristalerías Toro was a fully domestic developer and sponsor, and, in line with the developer-origin hypothesis (Figure 6.6), their being a local firm did seem to be related to the high local skills content of their project. The company was proud of local content, liked to learn and do things by themselves, and were partly driven by a desire to contribute to economic development. In fact, one important incentive to undertake their wind project was that they had set for themselves the goal that all of the electricity they used for their production process should come from renewable sources. The firm, moreover, built a recreation park and a hostel on the site of the wind farm, this to give something in return to the local community for their profiting from the location. Later, moreover, they started an environmental magazine venture. All of this suggests that they were indeed influenced by a developmental and an environmental ethos.

However, what was probably most conducive to the high degree of local skills content of their project was that, to be able to run its main glass manufacturing business, *Cristalerías Toro* – a diversifier – had developed capabilities which were closely related to those which were needed to develop and sponsor wind farms. Building, upgrading and running complex electrical facilities were common activities to the firm, this because their manufacturing plant had its own electricity system, which was in charge of their internal electrical engineering department. The only tasks which they felt not quite as confident about were those most idiosyncratic to the Wind sector, and for this reason the most novel to the country: the design tasks (Figure 6.4). The relatively early time at which the project was undertaken (Figure 6.8), however, was a time when foreign skills were less available, mainly because new subsidiaries were just starting to arrive in the country and high skilled Spaniards immigration had not yet taken off (Figure 6.1). This, and their preference for local content and for learning to do things by themselves, led them to take a hands-on approach, undertaking most tasks in-house, and, for some of the more novel design tasks, partnering with the few local ancillary service providers that were then in business.

The *Cristoro* project did not, however, run smoothly: in fact, it suffered from several problems, many of which can be attributed to the inexperience of its developer/sponsor, and which may not have been problems had they been more able and willing to tap into the skills of foreigners. The location where *Cristalerías Toro* had initially decided to build the facility, and where they had gone as far as assembling one aerogenerator, had to be abandoned when they discovered that the wind conditions were wholly inappropriate: a beginner's mistake if there was ever any. In addition, the project ran into problems with the procurement of aerogenerators: in trying to save costs, the firm bought second-hand some of the aerogenerators of the first phase of the project, a decision which left them without proper access to repair and maintenance services and therefore vulnerable to equipment failures – failures which did happen to them; and on another occasion, they bought equipment from a Chinese manufacturer that was able to provide some associated services, but only in the Chinese language: when the firm sent an engineer to commission the aerogenerators, *Cristalerías Toro* had to hire the expensive services of a translator to be able to understand him.

However, one key thing that the company did right was to undertake the project in a cautious, stepwise approach: first build one aerogenerator, then see how it runs; then build three more, see how well those fare; then try a new supplier, compare its performance with the previous one, stay with it if it's better and if not try a new one; expand the project further, test and compare – all of this over a period of about ten years and counting. This enabled the firm to avoid unbearably costly failures and to learn from its mistakes, and in this way turn up with a successful and on-going project with probably the highest degree of local content of all: even some of its higher-tech components, such as its SCADA control system, were developed by them, something which was unheard of in other wind farm projects.

The Case of Pattern Energy

Pattern Energy is a *NASDAQ Global Select Market* and *Toronto Stock Exchange*-listed firm from the US. The company is one of the rising new players in the worldwide NCREs sector: founded in 2009 by a group of US executives with a long history in the energy sector[132], it was by 2016 the owner of seventeen wind farms, most in the US and Canada[133]. The firm, which became active in Chile almost as soon as it was constituted (their entered their first Chilean project to the SEIA in 2009, the same year they were legally established in the US), self-develops, sponsors, and operates their own projects. Though they possess significant technological capabilities, they are not an engineering firm: they are what is known as an independent power producer, i.e. a firm whose core business is selling electricity.

132 www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=60520782
133 patternenergy.com/en/operations/

Pattern arrived in the country as the developers of the *El Arrayan* wind farm, a relatively large facility (Figure 6.7) with a very high degree of foreign skills content in project management and the design tasks (Figure 6.3). Early on in its development stage, this new subsidiary sent a team from the US to kick-start the venture: supported by the engineers and managers in their US headquarters, this team led the initial development of the project and undertook the resource prospection campaign mostly by themselves. Once the project was up and running, they hired a local executive and a small staff of just a handful of people to move it forward to the investment phase. The local team which was put in charge of the project was largely managerial, i.e. it was a team that could, by themselves, undertake tasks which required non-technological capabilities (such as the business model tasks), but that relied on the support of its parent firm for the design tasks, and on local engineering service providers for other tasks requiring design and engineering or production capabilities. Although *El Arrayan* started to be developed relatively early (Figure 6.8), it did not become operational until mid-2014. It was likely because, by this year, several other projects already had already been completed – and substantial experience had been accumulated by the locals who had participated in them – that the firm was able to do without foreign skills for most of the technological capability-requiring investment stage tasks.

The fact that the design tasks of the *El Arrayan* project were largely undertaken by foreigners (in this case, temporary migrants and foreign consultants) was, in all likelihood, related to the fact that the design tasks were the most novel of all, and that *Pattern USA* had strong design and engineering capabilities. The fact that the project's development phase was largely managed by foreigners (Figure 6.3), on the other hand, was somewhat out of the ordinary: as we've seen, in most projects this was a task with low degrees of foreign skills content, apparently because of its low 'tradability' (Figure 6.5). *Pattern*, however, was a firm that was bent on fast expansion, and this may have been the key to their decision to 'hit the ground running' by sending a full-fledged foreign team with the mission to get the project going.

The business strategy of *Pattern*, however, was arguably one that did not lead to as much knowledge spillover effects as the strategy of other new subsidiaries that engaged locals to a higher degree. Years after they had arrived in the country, *Pattern Chile* was still a small firm with relatively weak technological capabilities. A 'minimum-operations' subsidiary, if one may call it like that, with very low levels of independence. This, however, does not mean that its presence was negative: they, after all, developed and sponsored what was by 2016 the largest wind farm in the country, and were developing and likely to sponsor a large solar project – profiting from this but also helping lower the price of electricity and clean the Chilean energy matrix. But they contribution to economic development would have been larger if they had developed their local capabilities to a higher degree.

The Case of Enel Green Power

Enel Green Power is the renewable energies subsidiary of *Enel*, the colossal Italian multinational electricity utility. The firm was established in 2008 to group its parent firm's renewable energy assets, and by 2014 it was already present in several continents and had more than 3,500 staff[134]. As we've seen, the firm arrived after *ENEL* acquired *ENDESA Spain* in 2009, whom was at that time the owner of about 60% of the shares of *ENDESA Chile*. Having taken control of Chile's largest utility, the new Italian controller decided to leave the conventional energy business to *Endesa Chile* and move the renewable energy business to *Enel Green Power Chile (EGP Chile)*, which acted as a separate organization, and which was part of the same group but was not 60% but rather 100% owned by foreign capitals. *EGP Chile*, as we've seen, got a head start in the country because it took control of the assets and was able to build on the work of *Endesa Eco*, the renewable energies venture that *Endesa Chile* had created before the control of the company moved hands. By 2016, *EGP Chile* had developed at least four wind and six solar projects in the country[135], and had sponsored 5 of the former and 4 of the latter[136]. The firm had a relatively large staff of probably more than 200 employees, and served as the subsidiary of *EGP* not just for Chile but for the Andean countries.

Three of the projects in the sample were sponsored by *EGP Chile*: the *Valle de Los Vientos* and *Taltal* wind farms, and the *Lalackama* solar PV system. *Taltal* and *Lalackama* were both self-developed by the firm, while *Valle de los Vientos* was developed by a third-party and later sold to EGP. We will, therefore, focus on the first two, for it is these that show the behaviour of *EGP Chile* with regards to foreign skills content and capabilities.

Taltal had significantly more foreign skills content than *Lalackama* (Figure 6.3), which reflects a simple fact: *EGP Chile*'s staff was a mix of locals and foreigners that had arrived in the country not just to work on one project but to stay for longer periods. Although there were substantially more locals than foreigners in this staff, there was enough people in one and the other category to allow for project teams of different

[134] https://en.wikipedia.org/wiki/Enel_Green_Power
[135] And was probably developing many others which had not yet been submitted to the SEIA.
[136] The company was able to sponsor more wind projects than they had developed because, in addition to developing their own projects, they also sometimes bought them from the market.

compositions and thus for projects different foreign skills contents. It is nevertheless significant that the *Lalackama* project seems to have been one of the few solar projects where locals undertook most of the design tasks. This is indicative of the fact that *EGP Chile* was a subsidiary that did develop a wide range of local capabilities, partly by hiring foreigners with previous experience in other countries' NCRE sectors. Teamwork in such an environment, where there was probably no task that could not be undertaken by someone working in the same building, must have been a rich learning experience for both the locals and the foreigners – richer, no doubt, than working on a minimum operations subsidiary such as *Pattern Chile*. But the differences among the degree to which these two firms developed local capabilities was by no means *just* a difference in their business strategies: there was at least one objective difference that made it more feasible for *EGP Chile* to develop domestic capabilities to a much higher degree than *Pattern*: its much larger size, which meant that it could afford to have among its staff specialists whose salaries could only be justified if they worked on multiple projects. *Pattern* also had these, but they were in the US and did not interact nearly as much with the locals, in all likelihood leading to lesser knowledge spillover effects.

The Case of Selray

Selray was a 50/50 joint venture[137] among the small Chilean electric engineering services provider *Seltec* and the German independent solar power producer *Saferay*. Being located in the north of the country, the first of these firms, sensing new business opportunities were opening in the Solar sector, was looking for an opportunity to seize them, but did not possess the technological capabilities that would have allowed it to do so. The German firm, on the other hand, was a small but expanding multinational developer and sponsor of solar projects interested in making an inroad into Chile, one that did possess the required technological capabilities but did not know anything about the local milieu. The two firms, whose capabilities were complementary, were put in contact with each other by CORFO, whom somehow became aware of their reciprocal interests.

The joint venture developed and sponsored the *La Huayca I* solar PV system, one of the tiny first facilities that a handful of firms built from 2012 to 2014, before the much larger ones started to appear (Figure 6.8). As one can see in Figure 6.3, during the development stage the partnership had the Chilean party take charge of the general management and the environmental management, while the German party took charge of the design tasks and

[137] www.bnamericas.com/en/news/electricpower/chilean-power-project-approvals-fall-in-september

the business model tasks. This division of labor was fully in line with what one would expect given the capabilities of the partners: the German party took up the tasks that required the most complex and novel technological capabilities, and also the tasks that benefited the most from the business know-how of an established utility; and also with what one would expect given the ´tradability´ of the tasks: the Chilean party took up the tasks which were perceived as hardest to outsource. During the investment phase, the more 'novel' and more 'tradable' construction tasks also had more input from the Germans than the operation tasks. The modus operandi of the partnership was thus very much in line with the 'tradability' hypothesis. And, interestingly, it and also in line with the 'novelty' hypothesis. Thus even though this last hypothesis, as we saw, was not systematically supported by the data, this was a case where the mechanism it pointed to did seem to have been important.

The experience of these two firms shows the virtues of joint ventures as drivers of domestic capability accumulation processes. A number of foreign firms failed to establish a successful presence in Chile because they would not properly engage with the local milieu in all its regulatory and cultural complexities. And there must have been a number of domestic firms which, like *Seltec*, had an interest in either the Solar, the Wind, or the AD sectors but not the means to turn these intentions into an outcome (Dosi et al., 2001). Joint ventures, however, were exceptional in all three sectors, which is somehow puzzling and perhaps a fertile area for innovative public policy.

The Case of Schwager

Schwager is a more than 100 years old Chilean engineering solutions provider which started as a carbon mining firm. By the 1970s, the firm had been taken over by the state of Chile and had become active in the logistics business. The return of democracy in the 1990s led to its re-privatization, which saw it be split it in one firm that kept the mining business (and the name Schwager), and another that kept the logistics business. But soon after this, the mining business collapsed, and in response Schwager turned itself into a provider of specialised engineering services to the mining sector. Slowly, but steadily, the new business line grew – by 2014 the firm had perhaps about 1,000 employees –, and in the middle of the 2000s the company started to diversify into new economic activities. Their most significant diversification target was the renewable energies sector. But unlike most other actors who had set their eyes on this last, the company's chief objective in this area came to be to master and make a business out of biogas-based electricity generation technology.

Making a business out of biogas technologies, however, was far less straightforward than making a business out of wind or solar energy generation. As we've seen, in the former case the technologies are far less amenable to be bought off-the-shelf, the market is far more diverse and full of unexplored niches that may or may not represent viable entrepreneurial opportunities, and the possible business models are far more variable. Schwager was not immune to these difficulties, and it took them several years of trial and error to get to the point they desired. Wanting to fully master the technology so as to become independent of third party – i.e. foreign – technology providers, the firm engaged in several pilot projects to test different technologies and different business models: an R&D project where they explored the feasibility of growing and harvesting the *nopal* cactus for use as the biogas-generating substrate of electricity-generating anaerobic digesters; a few projects with university researchers; and so on, all this over a period of perhaps half a decade. The firm's breakthrough came with their partnering with a firm from the agro-industrial sector to develop and build milk processing facilities with integrated waste treating + electricity generating anaerobic digestion components. The first of these was *Purranque*, which was completed in 2011, and which was soon followed by *Puerto Octay* (2012) and *Osorno* (still under development).

As one can see in Figure 6.3, the *Purranque* facility had a very low foreign skills content: everything except for the design tasks was undertaken by teams with no foreign personnel (mostly *Schwager's* staff), and for this group of tasks the foreign skills content was not large. An anecdote reported to me about the origin of the share of foreign skills that went into the design tasks of this project is interesting because it shows how the accessibility to foreign skills was lower in the AD sector than it was in Wind and Solar. As it happens, *Schwager* had evaluated its options and decided to undertake the project fully in-house, and that the only reason foreigners ended up on the team that designed the facility was that they found out that a team of Mexican experts was temporary residing in the country working on another project. This presented the firm with an opportunity to hire them as consultants for a lower fee than they would have had to pay had they been the ones bringing the team from abroad in the first place. To play it safe with the design of the facility, *Schwager* seized the opportunity, and had these consultants give them feedback on their design. Had this opportunity not been presented to them, their project would have been made with zero foreign skills content, this not just because *Schwager* wanted to develop in-house technological capabilities, but also because such skills were just not as available as they were for Wind and Solar.

The case of *Schwager*, and its contrast with the one that will be reviewed next, suggests what may be the ingredients of success when access to foreign skills is hard to come by. The first of these ingredients is persistence: *Schwager* did not hit on their solution at the first try, but had to go through several rounds of trial and error until they came up with a viable solution. It is, however, fair to say that trial and error is far easier for a well-resourced firm like *Schwager* than for a start-up, which typically gets only one shot. The second ingredient is a cautious strategy: like *Cristalerías Toro*, *Schwager* did not immediately go for a large and uncertain investment, but engaged in the undertaking of small pilot investments whose primary purpose was developing in-house capabilities, not just technical but also managerial. Only when they were well prepared, they went for more sizable investments. And the third ingredient is finding a viable niche and focusing one's efforts on it, as *Schwager* did.

The Case of HBS

HBS is a sizable domestic diversified conglomerate whose main businesses are in the food production sector. Some years before they entered into the AD sector, the firm had made an inroad into the EG sector by installing a small gas-powered generation facility within one of their large orchards, one they used both to power their operations and to sell energy to the grid. The knowledge about the EG sector that they gained through this venture, plus the fact that their business was the kind that generated waste that could be valorized, led them to the decision to start *HBS Energía*. This subsidiary was to engage in the development of biogas projects, first to be sponsored by themselves and maybe in the future by others, once they had positioned themselves as competent technology providers which could serve as consultant project developers for third parties.

But this was never to happen. The flagship project of *HBS Energía*, the *Los Angeles* electricity-generating anaerobic digester, was completed and started operating in 2010, but turned out to be an unsuccessful venture. Lacking any previous experience with the technology, and not having undertaken any significant capability development investments before the project, the firm hired a German consultant/technology provider to lead the development of the project, whom primarily participated in its management and the design tasks (Figure 6.3). At the same time, the firm hired a local manager/engineer which had acquired significant technical experience working abroad, to act as the local counterpart of this foreign firm. Problems, however, quickly arose. For several reasons, the relation with the German firm went sour, and the local manager/engineer was fired. The facility that was in the end built was not well adapted to its context: it used needlessly expensive components, and was severely oversized, among other maladaptations. Having severed their relation with the German counterpart and with the one employee that had had previous experience with the technology, *HBS* ended up having to assign an engineer with no previous experience in the technology the herculean task[138] of running and trying to improve the performance of the plant through trial and error and consultation of instruction manuals. He did what he could, but with limited success. The plant never actually performed as expected, and *HBS Energía* became a dormant venture which had by 2016 not engaged much in further biogas projects.

The case of *HBS Energía* shows how an undue degree of reliance on foreign skills can sometimes be part of the problem rather than part of the solution. The approach followed by the firm contrasts sharply with that followed by *Schwager*, whom faced a similar challenge. While this last firm decided to invest time and resources in the development of in-house capabilities *before* committing large investments in the new ventures, *HBS Energía* proved willing to sponsor a large facility before it knew well what it was getting into, trusting that things would work well as long as a competent technology provider was brought into the project, and thinking perhaps that they could develop whatever capabilities would be required from their part on-the-go. However, sustained access to this technology provider proved to be something that should not have been taken for granted, and after this access was lost and the firm was left on their own, it discovered that it was not prepared to turn the white elephant they had paid for into a successful venture. In a sense, their mistake was like that of some early economic development scholars, who thought that all that was needed for countries to develop is that industrial plants be built in their territory. The firm moreover did not, as *Schwager* and *Cristoro*, start small and scale things only after they found a viable path, but rather went big from the outset. As this risky and high stakes bet did not end well, it is perhaps small wander that *HBS Energía* died.

[138] If these plants are harder to design than wind and solar ones, they are even harder to run and improve. The biological process which is involved is highly sensitive to variations in input substrate composition, input substrate feeding regularity, temperature, and other such variables. Running the plant optimally requires fine tuning all of these and making constant adjustments to adjust for the inevitable variations in the variables.

6.3. Wrapping Up

In this chapter, we sought to understand the nature of the sectoral-level aspects of the capability accumulation process that took place as the Wind, Solar and AD sectors developed, and the extent to which the capabilities of the entrepreneurial agents operating in these sectors were built upon the skills of foreigners.

The chapter started by going through a number of events that added to the respective sectoral-level capabilities. In the case of the Wind and Solar sectors, the Rural Electrification Program and its associated Barrier Removal Project added significantly to the early creation of human and organisational capital, particularly in the government but also more generally. Similarly, the CNE/GIZ collaboration, which led to the update of norms and regulations relevant to these two sectors, added to their organisational capital – again principally in their government-related aspects; and also, through the creation and systematisation of information about the Wind and Solar resource, to their knowledge capital. The birth of ACERA, the main industrial association of the NCREs in Chile, was also an important injection of sectoral-level organisational capital, one that enabled entrepreneurial agents to have a direct and effective channel through which they could state their points of view to governmental and other relevant actors. Adding to these, the rise of the renewables in CORFO's agenda led to the creation of the *Centro de Energías Renovables*, a government organ which further added to the organizational capital of the sector and that regularly strengthened its knowledge capital by collecting and systematizing relevant information; CORFO also fostered the development of human capital by funding technology missions and scholarships, and more generally supported the capabilities of the sectors by fostering the creation of a network of ancillary services providers. And the arrival of highly skilled Spanish immigrants was a significant injection of human capital for these two sectors. In the case of the AD sector, the only event that seems to have added significantly to the sectoral-level capabilities was the creation of Red Biogas. However, this network never became strong and eventually withered. This was arguably a reflection of the weaker sectoral cohesion that prevailed in this case, probably due to the sector's diversity and its relatively small potential market.

Having done this, we then undertook a more focused analysis aimed at understanding what influenced the extent to which the firm-level capabilities of the developers and sponsors of projects relied upon the skills of foreigners. In order to do this, we divided projects into six task groups whose completion required different kinds of capabilities (Amsden, 2001; Bell, 2007), and used data gathered through a questionnaire applied to engineers and managers of a sample of projects from each sector to create indicators of the degree to which foreign skills went into each of these task groups. An initial look at these indicators showed that there was substantial variation in the degree and distribution of the foreign skills content of the sample of projects, but there were also some visible localised regularities. We then set to test whether a number of hypotheses could explain some of these regularities.

The first step in this direction was to test whether two traits of the task groups – their 'novelty' and their 'tradability' – could explain why some of these tended to have higher foreign skills content than others. We conjectured that the more 'novel' and 'tradable' a task, the more likely developers and sponsors of projects would tap into foreign skills to complete them. The data, however, only supported one of these conjectures: while the more 'tradable' tasks did indeed have a noticeable tendency to have higher foreign skills contents, the more 'novel' tasks did not: there was no visible correlation among the perceived 'novelty' of a task and the degree to which foreigners participated on the teams that completed them.

The second step was to test whether certain traits of *projects*, rather than of *tasks*, had anything to do with their foreign skills content. This part of the inquiry focused on the design tasks only, which as we saw are arguably the most interesting because they are both the most 'novel' and among the most 'tradable', and because they arguably require the most advanced technological capabilities. The traits of projects that we hypothesised to be related to the foreign skills content of their design tasks were the origin of their developer, their size, and their timing. In the first case, we conjectured that projects developed by domestic firms would have lower foreign skills content than those developed by foreign and semi-foreign firms. In the second, we conjectured that larger projects would have higher foreign skills content than smaller ones. And in the third, we conjectured that earlier projects would have higher participation of foreign skills than later ones. The data, in this case, was in line with the developer origin and project timing hypotheses, but not with the project size hypothesis. Thus, projects developed by foreign and semi-foreign firms did tend to have higher foreign skills content in the design tasks than those developed by domestic firms, and earlier projects did have a tendency to have higher foreign skills content than later ones. In no case, however, was the data conclusive.

The third and final step of this second part of the chapter saw us taking an in-depth look at a selection of firms and their projects, aiming as above to understand why some relied more or less on foreign skills for certain tasks, but also to understand why and when a high or low foreign skills content was positive or negative from an economic development perspective. Rather than trying to provide a systematic account of the experience of each firm, what we did in this section was to pick those aspects of their experience that seemed most interesting to highlight because they illuminated one or another aspect of the underlying issues. This had the advantages of a) being feasible to do with the anecdotal (rather than systematic) data that I had collected for each of these firms; and b) providing a qualitative contrast that enabled a better interpretation of the quantitative data that we had gone through in the previous sections. The most interesting reflections that we engaged on in this section were those that showed how the foreign skills content of projects was influenced by firms' strategies, how these different strategies were sometimes influenced by objective realities such as their size, how some of these strategies led to higher knowledge spillover effects than others, and how overreliance on foreign skills sometimes came at a cost.

With this, we finish the chapter on domestic capabilities and foreign skills, and move on to the conclusions of this study.

Section / Concept	Operational Assumptions / Operational Definitions	Methods / Data
General	- **OA:** The most significant capability-development event of a new sector development process is the entry of entrepreneurial agents to it and their internal capability-development processes.	- **D:** Questionnaire responses. - **D:** Secondary documents. - **D:** Self-compiled projects database. - **D:** Scoping interviews.
Section 6.1.	- **OA:** Scoping interviews and revision of secondary documents provides a sufficiently rich basis to identify the most significant sectoral-level capability-development events for each sector.	- **D:** Secondary documents. - **D:** Scoping interviews. - **M:** Weighing of the available evidence base.
Section 6.2.	- **OA:** Tasks perceived as more 'novel' indicate tasks with higher capability-development requirements, and tasks perceived as 'hardest to leave to foreign firms' indicate tasks for which long-term residence in the country is a comparative advantage. - **OA:** The project developer undertakes (or coordinates and oversees) the design tasks.	- **D:** Questionnaire responses. - **D:** Scoping interviews. - **D:** Self-compiled projects database. - **M:** Development of indicators based on questionnaire responses. - **M:** Descriptive statistics. - **M:** Weighing of the available evidence base.

Table 6.1: Summary of data, methods and operational assumptions/definitions used in Chapter 6

Chapter 7

Discussion and Conclusions

In the previous chapters, we have gone through a detailed account of how three new infrastructure sectors developed in a hierarchical market economy (Schneider, 2013). To do this, we first developed the study's theoretical foundations (Chapters 2 and 3), and then addressed several questions that were informed by these foundations: *how, and when, did the entrepreneurial opportunities that underpinned the development of the Chilean Wind, Solar and AD sectors originate?* (Chapter 4); *what influenced the kinds of economic agent that contributed to the entrepreneurial function, and the nature of their contribution, in these sectors?* (Chapter 5); *what was the nature of the sectoral-level aspects of the processes of accumulation of capabilities that took place as these sectors developed?* (Chapter 6); and *what influenced the extent to which the capabilities of the entrepreneurial agents of these sectors came to depend on their ability to tap into the skills of foreigners?* (Chapter 6).

In this chapter, we will take a step back and discuss what we observed from four points of view. First, we will engage in some further reflections about the most notable features of the cases we studied, and about the extent to which these features can be generalised to other sectoral emergence processes. Second, we will discuss the policy implications of our findings. Third, we will highlight the methodological limitations of what we did. And, finally, we will highlight the main academic contributions of the study.

7.1. Further Reflections

As was anticipated in the discussion the study's analytical strategy (Section 3.2.4), in this section we will discuss the most notable features and the generalizability of the results that we arrived at for the three sectors we looked at. More specifically, our reflections will aim to cover three issues. First, we will reflect upon how, and why, new sectoral development processes may differ for different infrastructure sectors in HMEs (inter-sectoral differences). Second, we will consider how and why these emergence processes may differ from those of other kinds of sectors in these economies (cross-sectoral differences). And, third, we will ponder how and why these processes may vary from new infrastructure sector development processes taking place in other kinds of market economies (cross-national differences) (Schneider, 2013).

The main input for our reflections about inter-sectoral differences will be the contrast of the three cases we studied. As all of them were infrastructure sectors that developed within one and the same HME, their dissimilarities are in principle attributable to inter-sectoral rather than cross-sectoral or cross-national diversity, and their contrast is, therefore, an adequate method to inquire about this diversity. The main input for our reflections about cross-sectoral and cross-national heterogeneity, on the other hand, will be the most salient commonalities among the cases. These inter-sectoral commonalities point to things that, in principle, *may* be attributable to idiosyncrasies of infrastructure sectors, or to idiosyncrasies of HMEs. Highlighting these coincidences and reflecting on whether there is reason to believe they are indeed attributable to sectoral or national (i.e. institutional) particularities is, therefore, a suitable source of conjectures – given that we did not study other sectors or other MEs, we can do no more than conjecture – about the matter.

7.1.1. Inter-Sectoral Differences

Looking back at our three cases, the first inter-sectoral difference worth highlighting relates to the factors that technological regime theory focuses on (Breschi et al., 2000; Breschi and Malerba, 1997; Malerba and Orsenigo, 1993). As we've seen, this theory explains some features of the pattern of innovation in different sectors in terms of their technological opportunities, appropriability conditions, cumulative conditions, and the nature of their knowledge base. As shown in Section 5.3.1, the theory, although mainly informed by studies of manufacturing and high-tech services sectors, seems to be applicable infrastructure sectors. Thus, in that section, we were largely able to explain the relative importance of incumbent and new entrant entrepreneurial agents in terms of it. However, as we saw in Section 5.1, not all infrastructure sectors share the same technological regime, and, in line with the theory, this may lead to significant differences in their patterns of innovation. Although, in this case, the features of the regime relevant to the Wind and Solar sectors were not dramatically different from those relevant to the AD sector, this was arguably more of a coincidence than a specificity of infrastructure sectors, for it is not difficult to think of cases where these differences may be larger: an analysis of the regime relevant to, say, motorway infrastructure, would likely show this regime to present lesser technological opportunities, appropriability conditions, and cumulativeness conditions, making it likely that incumbents rather than new entrants would lead innovation in it. Thus, technological regime theory does seem to apply to infrastructure sectors, but not all infrastructure sectors share the same technological regime.

As we saw in Chapter 3, however, the supply-side explanation of sectoral patterns of innovation that that this theory proposes is a partial explanation, for demand-side factors are also often important: network externalities (Shy, 1996; Windrum and Birchenhall, 2005), bandwagon effects (Sutton, 1991), heterogeneous demand (Adner, 2002) and experimental users (Malerba et al., 2007) have all been shown to affect innovation patterns in several sectors. But do these, or other, demand-side factors also affect the pattern of innovation in infrastructure sectors? The analysis of our cases showed that, first, there could be significant inter-sectoral differences in the nature of the demand for the services provided by different kinds of infrastructure facilities; and, second, that these differences are indeed linked to their patterns of innovation.

As shown in Chapter 5, the demand for the waste treatment services provided by anaerobic digesters tended to be diverse but highly localised. Because the demand for these services was highly localised, anaerobic digesters normally needed to be built *within* broader production facilities. This meant that the investments that needed to be undertaken to support the transactions among the sponsor of an anaerobic digester and the user of the waste treatment services it provided were highly asset specific (Williamson, 1981, 1979). In other words, these investments were useless to provide the service to any other user than the owner of the broader facility. Because of the risk of opportunistic behaviour by the user/owner of the broader facility that this high asset specificity created, it was very uncommon for potential third-party sponsors, such as new domestic firms of new subsidiaries, to sponsor anaerobic digesters and provide the waste treatment service to the user for a payment. Instead, the sponsor of the facility and the user of the waste treatment service tended to be one and the same. Demand for the generation services provided by wind farms and solar PV systems, on the other hand, posed no such restrictions: due to the existence of a complex but essentially open energy market, the investments needed to support the transactions among the sponsor of a power plant and the user of the generation services it provided (the distributors and the large energy consumers) were not asset specific. In other words, these investments were not tied to any specific user: once built, power plants could be used to provide generation services to any user or to the SPOT market. In consequence, the users and the sponsors did not tend to be the same: any economic agent – including new entrants – was a potential sponsor.

These differences in the nature of the demand for waste treatment and electricity generation services, however, did not just affect the set of economic agents that could be their potential sponsors: they also affected the character of project development activity. As we saw in Section 5.3.3, when asset specificity did not force a conflation among service users and facility sponsors, this enabled the emergence of independent project developers – independent in the sense that they a) did not plan to sponsor the facilities they developed, and b) could not even be sure that they would find someone willing to sponsor them. Arguably, these developers injected a dose of dynamism to the first part of the entrepreneurial function in the Wind and Solar sectors that was absent from the AD sector, perhaps diminishing the chances of these two suffering from the self-discovery problems highlighted in (Hausmann and Rodrik, 2003). As noted in that section, what hindered the appearance of independent developers in the AD sector was that the localised nature of waste treatment services did not just make investment-stage investments be highly asset specific: it also made development-stage investments be so. Thus, it was not just the investments needed to support the transactions among sponsors of anaerobic digestion facilities and users of waste treatment services that were highly asset specific: those required to support the transactions among AD project developers and AD facility sponsors were equally so. These development-stage investments, too, were only useful to support transactions with a single counterpart, leaving the door open to opportunistic behaviour, and discouraging independent developers from making them.

The above suggests how it can be convenient to think of different infrastructure sectors as falling within a spectrum defined by two opposing ideal-types. At one extreme are the sectors engaged in the development and sponsorship of what we may call *supplementary* infrastructure facilities, and at the other are those supplying what we may call *income-generating* infrastructure facilities. Supplementary infrastructure facilities may be defined as facilities that regulatory, economical, technical, or whatever reasons force to be sponsored by immediate the users of the services they provide. And income-generating infrastructure facilities may be defined as facilities for which sponsorship by the immediate users of the services they provide presents no advantages over sponsorship by non-user-sponsors intent on operating them to provide the service to a third party for a return. Besides anaerobic digesters, facilities closer to the supplementary ideal-type would include electrical substations, astronomical observatories, military airports, and city roads. And besides wind farms and solar PV systems, income-generating facilities would include datacenters, housing developments, and hospitals. As we saw above, whether a certain kind of facility approximates or on another of these two ideal types will shape entrepreneurial activity in relation to it.

Although the examples above arguably approximate these two ideal-types, it is crucial to understand that whether a certain kind of facility is closer to one or another of these is a consequence of techno-economic factors such as economies of scale or historical lock-in (Arthur, 1989); and socio-institutional factors such as regulations or even habits. Because these factors can change, the degree to which any given kind of facility corresponds to one or another of these two ideal-types may change in time or in different places. But although not unchangeable, these techno-economic and socio-institutional factors can often be very persistent, forming what Geels and others have called a 'socio-technical regime' which tends to be stable over considerable stretches of time, timespans of decades or even centuries (Geels, 2005, 2002; Verbong and Geels, 2010).

7.1.2. Inter-Sectoral Commonalities and Cross-Sectoral / Cross-National Differences

Focusing now on the commonalities of the three cases that we studied, an interesting one is the fact that, of the various widely acknowledged structural change drivers that we identified in Chapter 3, one of them – changes in consumption preferences – was absent in all of the cases. As we saw in Chapter 4, all of the other well-recognized drivers – technical change, fluctuating resource availabilities, and evolving regulations, policies and institutions (Krüger, 2008; Kuznets, 1973; Silva and Teixeira, 2008) – played significant proximate roles[139] as factors that encouraged or hampered the development of one or more of the sectors, but not so with this one. On reflection, this likely was because the services provided by the infrastructure facilities that we studied (generation services and waste treatment services) were all intermediate, and hence were not exposed to direct consumer choice. Although not all infrastructure facilities provide intermediate services – high-speed trains and gas distribution networks are infrastructure systems that provide final consumer services or products –, this is not a rare occurrence, and in those cases when the infrastructure does cater directly to the final consumer, it is often a natural monopoly as in these two examples (Gómez-Ibáñez, 2009; Train and others, 1991).

If the above is correct, it means that infrastructure sectors are distinct from other kinds of sectors in that – with some exceptions – it is particularly difficult for people's preferences to influence their trajectory of development – except, perhaps, for people in relevant top decision-making posts. This casts in a new light the importance of social movements, one of the drivers that, in Chapter 4, we identified as a significant germination

---

139 Proximate roles in the sense that they influenced the attractiveness of the respective entrepreneurial opportunities *in the germination period*. As we saw in this chapter, understanding the role of one or more of these drivers needs to be done in relation to a certain timeframe, for structural change is continuous and over the long term all drivers matter and are intermingled.

driver of the Solar sector development process, but that is not very widely acknowledged in the structural change literature. One may argue that, because consumption preferences have lesser chances of directly influencing infrastructure development through what Hirschman (1970) called 'exit', what he called 'voice' – in particular, organized voice in the form of social movements – is more significant in these than in many other sectors, this because the difficulty of 'exiting' makes 'voice' the chief means through which laypeople can influence their evolution.

Another coincidence among the cases was that, as we saw by the end of Chapter 4, none of them was driven by internal technology-push events: in the one case where technology-push was significant (Solar), it had external origins. To all appearances, the reason for this was that Chile does not have a strong and dynamic manufacturing sector, one easily capable of engaging profitably, in the short term, and without external support in the development of the medium and high-tech key inputs used by any of the sectors we studied – or, for that matter, of engaging in the development of any but a few high-tech manufactures (Hausmann and Klinger, 2007b). All of these components were therefore imported, and, consequently, technology-push factors were external. The important thing to note is that this is not just a particularity of Chile, but rather a common trait of most HMEs – which, as we have seen, are characterized by low skill levels, and also by the widespread presence of MNEs which only rarely command their foreign subsidiaries to engage in spearhead technological development and endow them with the resources necessary to do so (Schneider, 2013). Thus, it would have been very remarkable if the development process of any of these infrastructure sectors had been driven in any significant measure by internal technology-push events – like happened with China's Solar sector (Liu and Goldstein, 2013), with the US' Wind sector (Nemet, 2009), and with the Netherlands' AD sector (Geels and Raven, 2006). Although this may sound unsurprising, it is worth mentioning because it is something that distinguishes new sector development processes in HMEs from those that take place in other MEs, and also something that – as we'll see in the next section – has some significant policy implications.

One more issue where the cases were in correspondence were the financial difficulties faced by new domestic firms and small diversifiers and incumbents in sponsoring facilities, particularly the larger ones. As we have seen, this is a problem known to be common to small firms in general (Beck and Demirguc-Kunt, 2006), but the issue is particularly significant in HMEs, which, as Schneider shows, tend to have very shallow financial markets (Schneider, 2013, pp. 72–80). The PhD thesis of O'Donovan (2016) on the development of the Wind sector in Ireland provides a good example to compare with, because it shows how new infrastructure sector development processes can unfold in the presence of more developed capital markets. In Ireland, new domestic firms and domestic diversifiers were the leading wind farm sponsors from the take-off of the sector in the early 2000s until 2007, when they ceased to invest nearly as much and started to be overtaken by foreign utilities (2016, p. 129). As shown by the author, these Irish firms mobilised financial resources 'through grants and joint venture capital funding' from institutional and other investors (2016, p. 161). And the reason why they stopped being the leading sponsors after 2007 was that the post 2008-crash economic recession made these resources far less accessible, giving an advantage to the large foreign utilities which then took over because these could finance projects through their balance sheets. Because of the underdevelopment of its financial markets, characteristic of HMEs, Chilean new domestic firms and small domestic diversifiers and incumbents did not have the same opportunities that their Irish counterparts did before the 2008 recession. Hence, it was exceptional for them to jump from project developers to project sponsors. Instead, their business model was to develop these projects and then have them acquired by foreign direct investors, which – as ECLAC says is common in Latin American HMEs – often had 'a stronger impact as a source of financing than as a transmitter of knowledge and technology or a catalyst of structural change' (Schneider, 2013, p. 84).

A further similarity among the three studied sectors was that all of them relied on foreign skills to a significant extent. As we saw in Chapter 6, although there was wide variation in this regard, and a few exceptional projects were completed without any foreign skills content at all, most projects had at least some highly skilled foreigners working on the teams that completed some of the tasks – especially, as documented in Section 6.2, on the more tradable tasks, on earlier projects, and on projects developed by foreign firms. That most projects had *some* degree of foreign skills content is undoubtedly related to the fact that the sectors under study were new to the country, and, therefore, their development was difficult to conceive without some input from highly skilled foreigners (Malerba and Nelson, 2011). And, as shown, the extensive participation of foreigners in the completion of projects' tasks was also related to the widespread presence of MNEs. However, the substantial reliance on foreign skills content may also have been linked to the fact that the sectors were developing in an economy locked in a low-skills equilibrium – like all HMEs tend to be (Schneider, 2013, pp. 113–128).

A final similarity among the cases was the notable extent to which foreign skills content went into tasks not considered among the most novel. As we also saw in Chapter 6, tasks perceived as more novel are arguably tasks requiring more capability-development investments. As one may have expected because of this, the more novel tasks tended to be those requiring technological rather than non-technological capabilities, which most authors agree are the scarcer capabilities in catching-up countries (Amsden, 2001; Bell, 2009; Lall, 1992). However, contrary to what one may have expected, these more novel tasks did not have systematically higher degrees of foreign skills content than the less novel tasks. The structural low skills equilibrium of Chile may have been part of the reason why even some not-so-novel tasks had considerable foreign skills content. After all, the fact that some of the twelve tasks I asked about on fieldwork interviews were perceived as less novel than others does not mean that they were not novel at all: the questionnaire I used asked interviewees to rank tasks' novelty relative to other tasks, and not in any absolute sense. However, this does not explain the lack of correlation between task novelty and foreign skills content: it just helps to understand why even some of the less novel tasks had this kind of foreign input.

More likely, the explanation of this unexpected result is again related to one of the structural characteristics of HMEs: the widespread presence and enormous economic significance of foreign MNEs. As we saw in Chapter 5, these were the most significant entrepreneurial agents on the Wind and Solar sectors, which are the sectors where the foreign skills content of tasks requiring non-technological capabilities was the more common. As Schneider argues, the subsidiaries of foreign MNEs in HMEs tend to be highly hierarchical – indeed, this is part of the reason why he calls these hierarchical market economies (Schneider, 2013, pp. 8–12). Now, one obvious means of maintaining this characteristically strong hierarchy is to fill top managerial positions with trusted foreign executives from the parent firms. Thus, although these foreign top managers may partly have been there because locals that could do their jobs were not widely available, it is very likely that they were also there to maintain chain of command.

7.2. Policy Implications

The debate on whether innovation tends to be more driven by demand-pull or supply-push factors – these last factors which, as we saw in Chapter 3, may be further divided into technology-push and capabilities-push factors – is also a debate on whether policies that focus on one or another of these areas are more effective to drive innovation (Ende and Dolfsma, 2005; Nemet, 2009; Peters et al., 2012; Taylor, 2008). Governments intending to drive infrastructure development with, typically, scarce economic resources and political capital, are often pressed by these limitations to focus on one or another of these different policy making arenas. In all of the cases we studied, the Chilean government disregarded technology-push policies, and instead favored demand-pull policies (e.g. the Renewables Obligation, and the regulatory tightening of environmental standards, see Chapter 4) and/or capabilities-push policies (e.g. CORFO's efforts to attract FDI, or the partnership of the CNE with the GIZ to develop capabilities in the state and the private sector, see Chapter 6).

This was arguably right. As we saw above, the reasons why no *internal* technology-push factors drove any of the three sectoral emergence processes were structural to the whole economy, and such structural issues are not easily dealt with using sectoral policies. This, at least, is what is suggested by the poor results of countries with similar structural problems that have tried technology-push policies in their mixes of infrastructure development policies, such as Brazil with its Wind sector (Rennkamp and Westin, 2013) and South Africa (also a HME according to Schneider, 2013, p. 243) with its Wind and Solar sectors (Baker, 2016). In terms of the 'product space' framework (Hausmann and Klinger, 2007b; Hidalgo and Hausmann, 2009, 2008; see a review of this in Section 2.2. of Chapter 2), the problem with these technology-push policies is that they aim for jumps to zones in the product space which are typically too far from the zones these low-economic-complexity economies inhabit (Hausmann et al., 2011). The policies are therefore not effective because they – like in the African saying – 'try to hit an elephant with a fist'. As argued by Bell and Albu in their research on industrial clusters (1999), and more generally by the literature on national innovation systems, technological development policies in these kinds of economies need to be broader and systematic, disregarding isolated and unconnected measures in favor of the creation of strong 'systems of knowledge accumulation' (1999, p. 1).

The above means that, in the context that normally prevails in HMEs, demand-pull and capabilities-push levers are far easier to pull effectively by governments than technology-push ones, and are thus more plausible policy targets. However, this does not mean that technology-push factors should be ignored in policy making. The case of the Solar sector, where the high price of solar technologies before the germination period would arguably have made support for the sector somewhat wasteful if it had taken place ten years earlier, shows how important it is for the state to be aware of the rate and direction of technical change and to adjust the timing of its policies so that these don't get deployed too early or too late. Although timing policies to make the best of changing technological opportunities is easier said than done, there are a number of experiences and methodologies to learn from that may make this more feasible, such as those analysed by research on technology foresight (Martin, 2010, 1995; Martin and Johnston, 1999). As argued by Perez and others, having at least a rough idea of the likely trajectory of technological progress and identifying windows of opportunity where the payoff of economic development policies is likely to be the largest is key for effectiveness (Marin et al., 2015; Perez, 1999; Perez and Soete, 1988). And, as the Solar case shows, this is as true for the development of infrastructure sectors as it is for that of any other sector. Infrastructure development policies that come too early may lead to wasting resources in fostering the diffusion of infrastructure which is unjustifiably expensive compared to what would need to be paid some years later or to what would need to be paid for emerging alternatives once these mature. And policies that come too late may unduly delay infrastructure upgrade. Prospective studies and strategic decision making, as that advocated in (Ortegón, 2007), can help to get the timing of policies right, and avoid either of these two pitfalls.

Leaving technology-push aside, one further issue of interest is which is the better among capabilities-push and demand-pull policies, the two policy arenas where governments in HMEs are more likely to effective encourage the development of new infrastructure sectors. On this matter, the results suggest that none of these is invariably better than the other. As we saw in Chapter 4, not all innovations are attractive (or equally attractive) entrepreneurial opportunities; and, as argued by Hausmann and Rodrik (2003), not all attractive entrepreneurial opportunities are pursued by dynamic entrepreneurial agents. If the diffusion of a desirable (from a social welfare point of view) infrastructure innovation which is an attractive entrepreneurial opportunity is hindered by a weak entrepreneurial function, i.e. by a situation where no one is stepping up to pursue the opportunities, then capability-push policies seem more adequate than demand-pull ones, for it is these that directly target the underlying causes, namely an inability of potential entrepreneurial agents to discover and/or pursue the opportunities. If, on the other hand, the opportunities are just not attractive enough to warrant the efforts of potential and able entrepreneurial agents, then demand-pull policies that shift the demand curve to the right are likely to be more effective. Thus, this is a policy problem where armchair recommendations are unlikely to work. As Rodrik put it, diagnostics are required before prescription (Rodrik, 2010). Diagnostics, however, are not always easy or even viable, in which cases this is empty advice. However, sometimes they are. In cases when the infrastructure innovations in question are not too costly, a good diagnostics tool may be to sponsor pilot or demonstration projects and to carefully evaluate their performance, finding out, if they fail, why they did so; and making sure, if they succeed, that their success is widely publicized, for if they do this means that what's needed the most is for potential entrepreneurial agents to discover the opportunities.

Moving on to the implications of the inter-sectoral variations discussed above, the differences among income-generating and supplementary infrastructure suggest different policy approaches may work better to encourage their respective development. Since, as we've discussed, a) investing in novel kinds of supplementary infrastructure is unlikely to be an attractive entrepreneurial opportunity to any other than a reduced number of potential sponsors; and b) discovering concrete contexts where supplementary infrastructure innovations can be valuable, and developing specific projects for these contexts, is unlikely to be stimulated by dynamic independent developers; then policies to encourage the diffusion of supplementary infrastructure ought to place particular emphasis on c) identifying these few potential sponsors and increasing their awareness of the opportunities; d) identifying consultants and consultancies with related capabilities and fostering the diversification of their offer of engineering services so that it includes services relevant to the target infrastructure; and e) placing these potential sponsors and consultants in contact with each other. Policies to encourage the diffusion of income-generating infrastructure, on the other hand, are arguably less in need of identifying and targeting specific groups of potential entrepreneurial agents, and can focus instead on encouraging the entry of new ones by designing fair markets that, first, don't favor the incumbents with the oligopolistic advantages that are so typical of HMEs, and that, second, lower the barriers to entry faced by disadvantaged potential new entrants such as small domestic firms.

As discussed above, the design of policies to encourage the diffusion of supplementary infrastructure innovations ought to take into consideration their differences with income-generating infrastructure innovations, but policy makers should also factor in the possibility of turning the former into the latter by fostering the development of new markets that spur business model innovations. This kind of transformation has taken place in the past. A notable example, in fact, is the electricity generation service, which in most places used to be integrated with electricity transmission and distribution, leading to generation facilities being considered as supplementary infrastructure of integrated electricity systems which – largely because electricity transmission and distribution are natural monopolies – were typically run by monopolistic or oligopolistic utilities. In such conditions, it did not make business sense to sponsor these facilities for any other than these utilities. However, the regulatory de-integration of generation, transmission and distribution systems that took place in line with the proposals in (Joskow and Schmalensee, 1983) changed this in many places, opening the generation sector to new entrants that could build generation facilities and sell electricity in carefully designed markets, independent of whether they had stakes on the transmission and distribution infrastructure. Many countries have adopted this and related regime-changing approaches (such as the embracement of public-private partnerships, see Engel, 2014) to the challenge of encouraging new infrastructure investment in various sectors, and in particular in the transport sector. These, no doubt, are not a panacea[140], but when well designed, managed, and adjusted to fit changing circumstances, they've often proved successful (Engel et al., 2001; Lucioni, 2009; Sánchez and Wilmsmeier, 2005).

One feature that is likely to influence how and by whom the entrepreneurial function is performed is whether the infrastructure in question is the kind that makes more sense to build as large-centralized facilities, of the kind that makes sense to build as small-independent facilities, or of some intermediate form. Some kinds of infrastructure facilities, such as nuclear power plants, GPS systems, high-speed train lines, and HVDC transmission lines, tend to make economic sense only if they are relatively large in scale compared to other infrastructure investments. Other infrastructure, such as the wind farms and solar PV systems that we studied, as well as irrigation schemes and bridges, may make economic sense as either large-centralized or small-independent depending on various circumstances. And yet some other kinds of infrastructure, such as anaerobic digesters or fuel filling stations, tend to be small and distributed and only rarely make economic sense as large and centralised facilities.

This distinction has interesting policy implications – in particular, some regarding the potential role of FDI in their development. The aforementioned financial difficulties that sponsoring large-centralized infrastructure facilities poses to small potential sponsors in HMEs, and the lack of technological dynamism of many of the larger diversified business groups – groups that would be more able to sponsor them – of these economies (Schneider, 2013, pp. 64–70), arguably make the fresh financial flows provided by FDI more of a necessity for large-centralized than for small-independent infrastructure. It is also possible – though this is subject to empirical validation – that the former would more easily attract new FDI, for a) this kind of infrastructure may generally require less knowledge of the local milieu than its small-independent counterpart, and b) the set-up costs of establishing a presence in a new location may only be justified if the investments to be made are large enough.

This, however, does not mean that steadfast support of FDI as a way to encourage the diffusion of large-centralized infrastructure is always the best option. In line with the findings of much previous research on FDI and development (Agosin and Machado, 2005;

[140] E.g. they may lead to distributional issues or coordination issues.

Amsden, 2009, 2001; Schneider, 2013), our results showed that FDI can have a significant opportunity cost associated with the displacement of potential local initiative – one which can only be estimated counterfactually and which may moreover affect only the medium-to-long-term, often leading to it being ignored even if it's not at all clear whether factoring it in would still make FDI-encouragement look as attractive a policy option. On this matter, it is important to note that the issue is not whether to allow or not allow FDI, but rather how much FDI to allow and in which areas: there is a wide middle ground between a policy of unabashed FDI encouragement and a closed-doors policy, and policies that strike a virtuous middle-ground between these two extremes are anything but inconceivable.

A final implication of our findings relates to the different degrees of difficulty that entrepreneurial agents engaged in different kinds of infrastructure undertakings may have in accessing foreign skills. If, as our results suggest (Chapter 6), the entrepreneurial agents of infrastructure sectors engaged in building small-independent and supplementary infrastructure are less likely to have easy access to foreign skills, then, all other things being equal, policies to encourage the diffusion of this kind of infrastructure ought to place greater emphasis in the accumulation of the relevant skills by the local people, as these will in these cases be crucial to the capabilities of these entrepreneurial agents and therefore to the strength of the entrepreneurial function.

7.3. Methodological Limitations

As with all case study research, the chief limitation of this study is the small size of the sample of sectors that we studied (just three sectors) in relation to the whole universe of reference (all new infrastructure sector development processes in all HMEs). Although the contrast of these three cases – and in particular the contrast of the Wind and Solar sectors with the AD sector – was the source of informative reflections, it is clear that these do not encompass the whole range of diversity among infrastructure sectors, and that some areas of unexplored variability may be as significant determinants of the trajectory of their development as the areas that the study of these three sectors enabled us to explore. By way of example, there are some infrastructure sectors – e.g. highways – where the entrepreneurial role of the state as a project sponsor has traditionally been dominant or at least highly significant, and some others – e.g. space launch systems or astronomical observatories – engaged in the construction infrastructure which is highly specialized and which caters to a highly specific and sometimes largely international demand. In all likelihood, the distinctive features of these and other sectors will affect their process of development in ways which we did not consider in this study.

In addition to the above, the study only looked at infrastructure sectors within one single HME, not directly comparing their process of development with that of other sectors in other MEs. Because of this, the reflections that we went through in Section 7.1.2 about inter-sectoral commonalities and their possible relation to cross-sectoral and cross-national differences ought to be taken with particular caution, for these were more the result of logical analysis than of empirical fact checking.

Besides these general limitations, each of our three empirical chapters had some more specific limitations. In the case of Chapter 4 – where one of our main goals was to evaluate how attractive it was to build a Wind, Solar or AD facility in the take-off year compared to ten years before –, crucial limitations were the counterfactual nature of the argument, and the lack of quantitative data to judge the impact of some of the events. In Chapter 5, one important limitation was that our descriptions of the technological regimes prevalent in the WWT and EG sectors were not based on systematically acquired quantitative data (as in the original studies, see for example Breschi and Malerba, 1997), but rather on qualitative information from fieldwork notes and secondary documentation, which in some respects makes them less objective; similarly, our description of the characteristics of the developer>sponsor and sponsor>user transactions (frequency, uncertainty, asset specificity) was appreciative, and therefore debatable. Finally, in Chapter 6, one crucial limitation was the small size of the sample of projects that we studied (particularly in the case of anaerobic digesters, where the sample was moreover not representative), which only enabled us to run simple descriptive analyses, and reach only tentative conclusions.

7.4. Academic Contributions

On the chapters where we went through the theoretical underpinnings of this exploratory study (Chapters 2 and 3), I argued that knowledge about how new-to-the-country infrastructure sectors emerge in HMEs is far less developed than knowledge about how other kinds of sectors – and, in particular, new-to-the-world high-tech manufacturing sectors in other MEs – emerge. The studies of Utterback and colleagues on the product life cycle (Utterback and Abernathy, 1975; Utterback and Suárez, 1993), those of Klepper on the evolution of new industries and industrial clusters (Klepper, 2010, 1997; Klepper and Graddy, 1990), and those of Boschma, Neffke and other economic geographers on regional diversification and industry relatedness (Boschma et al., 2013; Neffke et al., 2014, 2011) – which are arguably among the most theoretically advanced – have largely focused on new-to-the-world high-tech manufacturing sectors in LMEs or CMEs. In their research on structural change in some late-developing NMEs and HMEs, Kim and Amsden have extended some of these ideas to other kinds of market economies, and also partly to new-to-the-country rather than new-to-the-world innovation. However, the focus of their studies has still primarily been high-tech manufacturing or services (Amsden, 2003, 2001, 1989; Kim, 1997). Although this listing is not extensive, it reflects the general neglect of infrastructure sectors by research on sectoral development and evolution (Malerba, 2007; Malerba and Orsenigo, 1996) and more broadly on structural change (Krüger, 2008). The first academic contribution of this study has been to address this issue by studying the process of development of three new-to-the-country *infrastructure* sectors *in HMEs*, this using a theoretical framework that links with and expands on the ideas of many of the aforementioned works.

In Chapter 2, we saw how many theoretical studies look at the structural change process at the country-level and identify a number of factors which are thought to be its main drivers (e.g. Acemoglu and Guerrieri, 2006; Baumol et al., 1991; Chang, 1994; Kuznets, 1973; Lewis, 1954; McMillan and Rodrik, 2011). Structural change, however, is known to be the aggregate result of turbulent change at the micro-level (Krüger, 2008). A second academic contribution of this study has been to look at this process at this more disaggregate level, but without losing sight of the fact that what takes place in this realm is affected by the broader factors identified in this literature, and which we considered in Chapter 4. From this bottom-up view, the unit of analysis overlaps with that of scholars studying sectoral transformation processes (Malerba, 2007; Malerba and Orsenigo, 1996) and firm-level capability accumulation processes (Amsden and Hikino, 1994; Bell and Pavitt, 1995). This being so, ideas coming from this research permeate this study's theoretical foundations, and linking these with those of the country-level studies of structural change can also be considered one of its academic contributions.

A third way in which this study makes an arguably original academic contribution is by its conception of entrepreneurship as a function, a function whose character (as we saw in Chapter 2) is sector specific and which may be jointly undertaken by heterogeneous entrepreneurial agents that – as happened in all three cases that we studied – do not necessarily contribute to its undertaking in the same ways. As we saw in Chapter 3, the idea of entrepreneurship as a function is not new (Kirzner, 1999, 1997). However, its application in an empirical study such as this one is arguably more novel. By organizing the study around this idea, we were better able to appreciate the role of the project developers in infrastructure sector innovation, thus complementing inquiries that go deeper into the role of the sponsors and the financiers, all of which – because they make the larger investments

– are often given prime of place (e.g. Mazzucato and Semieniuk, 2016). Interestingly, the idea is adaptable to the study of other sectors – all sectors may be defined in terms of certain kinds of entrepreneurial opportunities, and all sectors have economic agents actively searching for and pursuing these opportunities –, thus providing a useful framework for comparative studies of entrepreneurship in different sectors.

Appendix A

Interviewee	Kind of organization	Fieldwork data-gathering activities conducted for each interviewee								
		Project questionnaire			Activities questionnaire			Open-ended questioning		
		Wind	Solar	AD	Wind	Solar	AD	Wind	Solar	AD
PPOT34	New domestic firm						x			x
PPTX31	New subsidiary	x			x			x		
PPNQ09	Domestic diversifier			x			x			x
PPMM90	New domestic firm					x		x	x	
PPUN76	New subsidiary	x						x	x	
PPAM23	DJ joint venture				x			x		
PPUQ41	New subsidiary	x						x		
PPUX35	New subsidiary				x			x		
PPVS35	New subsidiary	x			x			x		
PPER25	DUFC incumbent							x		
PPYH83	New domestic firm							x		
PPCH11	New subsidiary		x			x			x	
PPYX64	Government							x	x	x
PPKS01	New domestic firm							x	x	
PPJA01	Domestic incumbent							x	x	x
PPLC01	Domestic diversifier							x	x	x
PPEJ83	New domestic firm	x						x		
PPYY55	Domestic incumbent							x	x	
PPHR82	Domestic diversifier							x		
PPWL66	New domestic firm							x		
PPUQ34	New subsidiary	x			x			x		
PPKL99	New subsidiary							x	x	
PPNS01	Foreign incumbent							x		
PPUI83	DJ joint venture							x		
PPYH72	Domestic diversifier	x						x		
PPHQ93	Other							x	x	x
PPYM56	Other							x	x	x
PPXH84	University									x
PPUW34	Domestic diversifier	x						x		
PPYG35	Domestic diversifier			x			x			x
PPGY34	New domestic firm			x			x			x
PPTY35	New subsidiary	x			x			x		
PPEF35	Other									x
PPUZ52	Other									x
PPZX82	DUFC incumbent				x			x		
PPUC66	Domestic diversifier	x						x		
PPWF32	DF joint venture	x			x			x		
PPUX25	Domestic diversifier			x			x			x
PPER35	Domestic diversifier				x		x			x
PPYB35	Other									x
PPWE35	New subsidiary	x			x			x		
PPJF83	DF joint venture				x	x		x		
PPKQ20	New subsidiary				x			x		
PPKK44	New subsidiary					x			x	
PPKF85	New subsidiary		x			x			x	

PPWK31	Domestic diversifier									x
PPJP35	New subsidiary		x						x	
PPXH49	New subsidiary		x			x			x	
PPAQ74	New subsidiary						x			
PPYU32	New domestic firm		x						x	
PPCK05	DUFC incumbent		x				x			x
PPNC43	New domestic firm							x	x	
PPBT35	New subsidiary		x						x	
PPUY32	DUFC incumbent	x						x		
PPPL56	New subsidiary								x	
PPSE07	New subsidiary		x			x			x	
PPJS45	New subsidiary		x						x	
PPYL82	DUFC incumbent									x
PPOL73	DF joint venture		x			x			x	
PPHW74	Other							x	x	x
PPHR26	Other							x	x	x
PPNT94	Other					x			x	
PPZL84	New subsidiary					x			x	
PPTU69	New domestic firm								x	
PPXB35	New subsidiary		x			x			x	
PPYM81	DF joint venture		x			x			x	
PPAR90	New subsidiary					x			x	

Appendix B

B.1. Project development in the Wind sector

Sector: Wind Right: Start of development Down: Kind of developer Content: Aggregate number of projects	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Domestic Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUFC Incumbents	0	0	0	0	0	0	0	1	1	2	2	2	4	4	4	4	4
Foreign Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Diversifiers	0	0	0	0	0	0	0	0	0	1	3	3	4	4	6	6	10
DUFC Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign Diversifiers	0	0	0	0	0	0	0	4	4	4	5	5	5	6	6	6	6
New Domestic Firms	0	1	1	1	1	1	1	1	1	2	3	5	6	9	9	12	14
D-F Joint Ventures	0	0	0	0	0	0	0	0	1	2	2	2	5	7	11	12	12
New Subsidiaries	0	0	0	0	0	0	0	1	3	9	14	16	20	24	28	32	37
Unknown / Other	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	3
Total (Number of Projects)	0	1	1	1	1	1	1	7	10	20	29	33	44	56	67	75	86

(Data used in Figure 5.2)

B.2. Project development in the Solar sector

Sector: Solar Right: Start of development Down: Kind of developer Content: Aggregate number of projects	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Domestic Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
DUFC Incumbents	0	0	0	0	0	0	0	0	0	0	0	1	1	2	4	4	4
Foreign Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Domestic Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5	10	10

DUFC Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	6	6
New Domestic Firms	0	0	0	0	0	0	0	0	0	0	0	0	3	6	21	29	33
D-F Joint Ventures	0	0	0	0	0	0	0	0	0	0	0	2	3	6	8	10	11
New Subsidiaries	0	0	0	0	0	0	0	0	0	1	4	10	15	48	89	109	131
Unknown / Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5
Total	0	0	0	0	0	0	0	0	0	1	4	13	23	65	131	170	202

(Data used in Figure 5.3)

B.3. Project development in the AD sector

Sector: AD Right: Start of development Down: Kind of developer Content: Aggregate number of projects	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Domestic Incumbents	0	0	0	0	2	3	6	7	7	8	8	8	9	9	9	9	13
DUFC Incumbents	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
Foreign Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Diversifiers	0	0	0	0	0	0	0	0	0	0	1	3	3	4	4	4	4
DUFC Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Domestic Firms	0	0	0	0	0	0	1	2	7	12	17	21	28	31	35	35	36
D-F Joint Ventures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Subsidiaries	0	0	0	0	0	0	5	9	9	10	10	11	11	11	11	11	11
Unknown / Other	1	1	5	5	5	5	7	9	12	14	15	18	22	22	24	25	25
Total	1	1	5	5	7	8	19	28	36	45	52	62	74	78	84	85	90

(Data used in Figure 5.4)

B.4. Project sponsorship in the Wind sector

Sector: Wind Right: Start of operation Down: Kind of sponsor Content: Aggregate installed capacity in MW	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Domestic Incumbents	0	0	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
DUFC Incumbents	0	0	0	0	0	0	0	0	18.2	18.2	116	116	116	116	116	116	116	118
Foreign Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Diversifiers	0	0	0	0	0	0	0	0	0	0	6.24	8.58	8.58	8.58	26.3	31.5	42.8	42.8
DUFC Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	36	36
Foreign Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	20	20	20	20	20	20
New Domestic Firms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-F Joint Ventures	0	0	0	0	0	0	0	0	0	0	46	46	46	46	46	46	46	69
New Subsidiaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	151	498	606	718
Unknown / Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	45	45
Total (MW)	0	0	2.57	2.57	2.57	2.57	2.57	2.57	20.7	20.7	171	173	193	193	362	795	915	1051

(Data used in Figure 5.5)

B.5. Project sponsorship in the Solar sector

Sector: Solar Right: Start of operation Down: Kind of sponsor Content: Aggregate installed capacity in MW	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Domestic Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUFC Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	23	23
Foreign Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.05	2.05	2.05
DUFC Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

New Domestic Firms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.88	5.88	5.88
D-F Joint Ventures	0	0	0	0	0	0	0	0	0	0	0	0	0	2.43	2.43	2.43	121	221
New Subsidiaries	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	2.36	351	1072	1797
Unknown / Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267
Total (Capacity)	0	0	0	0	0	0	0	0	0	0	0	0	0	3.53	6.79	363	1223	2315

(Data used in Figure 5.6)

B.6. Project sponsorship in the Wind sector

Sector: AD Right: Start of operation Down: Kind of sponsor Content: Aggregate installed capacity in mm3 bg/y.	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Domestic Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	8.32	8.32	8.32	8.32	8.32
DUFC Incumbents	0	0	0	0	0	0	0	0	0.19	0.19	24.2	24.2	24.2	55.7	55.7	55.7	55.7	55.7
Foreign Incumbents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic Diversifiers	0	0	4.48	4.63	25.7	25.7	26.5	27.1	54.4	66.1	66.1	69.1	72.2	74.7	83.2	84.4	85.1	85.5
DUFC Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign Diversifiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Domestic Firms	0	0	0	0	0	0	0	0	0	0	0	0	2.1	3.15	3.15	3.15	4.2	8.58
D-F Joint Ventures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Subsidiaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown / Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	4.48	4.63	25.7	25.7	26.5	27.1	54.6	66.3	90.3	93.3	98.5	142	150	152	153	158

(Data used in Figure 5.7)

References

Acemoglu, D., Guerrieri, V., 2006. Capital Deepening and Non-Balanced Economic Growth (Working Paper No. 12475). National Bureau of Economic Research.

Acemoglu, D., Johnson, S., Robinson, J., 2004. Institutions as the Fundamental Cause of Long-Run Growth.

Acemoglu, D., Robinson, J.A., 2013. Why Nations Fail: The Origins of Power, Prosperity and Poverty. Profile Books, London.

Acs, Z.J., Audretsch, D.B., 1990. Innovation and small firms. Mit Press.

Adewuyi, A.O., Ademola Oyejide, T., 2012. Determinants of backward linkages of oil and gas industry in the Nigerian economy. Resour. Policy 37, 452–460. doi:10.1016/j.resourpol.2012.06.007

Adner, R., 2002. When are technologies disruptive? a demand-based view of the emergence of competition. Strateg. Manag. J. 23, 667–688. doi:10.1002/smj.246

AFRICA, I., 2006. Doubling Aid: Making the “Big Push” work.

Aghion, P., Howitt, P., 1990. A model of growth through creative destruction. National Bureau of Economic Research.

Agosin, M.R., Machado, R., 2005. Foreign Investment in Developing Countries: Does it Crowd in Domestic Investment? Oxf. Dev. Stud. 33, 149–162. doi:10.1080/13600810500137749

Amsden, A.H., 2009. Nationality of Firm Ownership in Developing Countries: Who Should “Crowd Out” Whom in Imperfect Markets? Ind. Policy Dev. Polit. Econ. Capab. Accumul. 409–423.

Amsden, A.H., 2003. Beyond Late Development: Upgrading Policies in Taiwan. MIT Press, Cambridge, Mass.

Amsden, A.H., 2001. The Rise of “the Rest”: Challenges to the West from Late-Industrialization Economies. Oxford University Press.

Amsden, A.H., 1989. Asia’s next giant: South Korea and late industrialization. Oxford University Press.

Amsden, A.H., Hikino, T., 1994. Project Execution Capability, Organizational Know-how and Conglomerate Corporate Growth in Late Industrialization. Ind. Corp. Change 3, 111–147. doi:10.1093/icc/3.1.111

Antoncic, B., Hisrich, R.D., 2003. Clarifying the intrapreneurship concept. J. Small Bus. Enterp. Dev. 10, 7–24. doi:10.1108/14626000310461187

ANTUKO, 2015a. Antuko Weekly Report - August 24th/30th 2015.

ANTUKO, 2015b. Antuko Weekly Report - May 11th/17th 2015.

ANTUKO, 2015c. Antuko Weekly Report - July 13th/19th 2015.

Araneda, J.C., Mocarquer, S., Moreno, R., Rudnick, H., 2010. Challenges on integrating renewables into the Chilean grid, in: Power System Technology (POWERCON), 2010 International Conference on. IEEE, pp. 1–5.

Archibugi, D., Coco, A., 2005. Measuring technological capabilities at the country level: A survey and a menu for choice. Res. Policy 34, 175–194.

Arrow, K.J., 1962. The economic implications of learning by doing. Rev. Econ. Stud. 29, 155–173.

Arthur, W.B., 1994. Increrasing returns and path dependence in the economy. University of Michigan Press.

Arthur, W.B., 1989. Competing Technologies, Increasing Returns, and Lock-In by Historical Events. Econ. J. 99, 116–131. doi:10.2307/2234208

Asiedu, E., 2006. Foreign direct investment in Africa: The role of natural resources, market size, government policy, institutions and political instability. World Econ. 29, 63–77.

Azariadis, C., Drazen, A., 1990. Threshold Externalities in Economic Development. Q. J. Econ. 105, 501–526. doi:10.2307/2937797

Baer, W., 1972. Import Substitution and Industrialization in Latin America: Experiences and Interpretations. Lat. Am. Res. Rev. 7, 95–122.

Baily, M.N., Chakrabarti, A.K., Levin, R.C., 1985. Innovation and productivity in US industry. Brook. Pap. Econ. Act. 1985, 609–639.

Baker, D.L., 2016. Technology Development in South Africa: The Case of Wind and Solar PV (SSRN Scholarly Paper No. ID 2745973). Social Science Research Network, Rochester, NY.

Bakker, R.M., 2010. Taking Stock of Temporary Organizational Forms: A Systematic Review and Research Agenda. Int. J. Manag. Rev. 12, 466–486. doi:10.1111/j.1468-2370.2010.00281.x

Balassa, B., 1965. Trade Liberalisation and “Revealed” Comparative Advantage1. Manch. Sch. 33, 99–123. doi:10.1111/j.1467-9957.1965.tb00050.x

Baller, S., Dutta, S., Lanvin, B., 2016. The Global Information Technology Report 2016.

Battisti, G., Pietrobelli, C., 2000. Intra-Industry Gaps in Technology and Investments in Technological Capabilities: Firm-level evidence from Chile. Int. Rev. Appl. Econ. 14, 253–269. doi:10.1080/02692170050024778

Baumol, W.J., 1996. Entrepreneurship: Productive, unproductive, and destructive. J. Bus. Ventur. 11, 3–22. doi:10.1016/0883-9026(94)00014-X

Baumol, W.J., Blackman, S.A.B., Wolff, E.N., 1991. Productivity and American leadership. MIT press Cambridge, MA.

Beck, T., Demirguc-Kunt, A., 2006. Small and medium-size enterprises: Access to finance as a growth constraint. J. Bank. Finance 30, 2931–2943. doi:10.1016/j.jbankfin.2006.05.009

Beesley, M.E., Hamilton, R.T., 1984. Small firms' seedbed role and the concept of turbulence. J. Ind. Econ. 217–231.

Bell, M., 2009. Innovation capabilities and directions of development.

Bell, M., 2007. Technological learning and the development of production and innovative capacities in the industry and infrastructure sectors of the Least Developed Countries: What roles for ODA. UNCTAD Least Dev. Ctries. Rep. Backgr. Pap.

Bell, M., 2006. Time and technological learning in industrialising countries: how long does it take? How fast is it moving (if at all)? Int. J. Technol. Manag. 36, 25–39.

Bell, M., Albu, M., 1999. Knowledge Systems and Technological Dynamism in Industrial Clusters in Developing Countries. World Dev. 27, 1715–1734. doi:10.1016/S0305-750X(99)00073-X

Bell, M., Pavitt, K., 1997. Technological accumulation and industrial growth: contrasts between developed and developing countries. Technol. Glob. Econ. Perform. 83–137.

Bell, M., Pavitt, K., 1995. The development of technological capabilities. Trade Technol. Int. Compet. 22, 69–101.

Bell, M., Scott-Kemmis, D., Satyarakwit, W., 1982. Limited learning in infant industry: a case study. Econ. New Technol. Dev. Ctries. 138–156.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Res. Policy 37, 407–429.

Bhagwati, J., Panagariya, A., Srinivasan, T.N., 2004. The Muddles over Outsourcing. J. Econ. Perspect. 18, 93–114.

Blundell, R., 1988. Consumer Behaviour: Theory and Empirical Evidence--A Survey. Econ. J. 98, 16–65. doi:10.2307/2233510

Boschma, R., 2005. Proximity and Innovation: A Critical Assessment. Reg. Stud. 39, 61–74. doi:10.1080/0034340052000320887

Boschma, R., Minondo, A., Navarro, M., 2013. The Emergence of New Industries at the Regional Level in Spain: A Proximity Approach Based on Product Relatedness. Econ. Geogr. 89, 29–51. doi:10.1111/j.1944-8287.2012.01170.x

Bradford, C.I., 1987. Trade and structural change: NICs and next tier NICs as transitional economies. World Dev. 15, 299–316.

Braudel, F., 1967. Civilization and Capitalism, 15th-18th Century, Vol. I: The Structure of Everyday Life. University of California Press.

Brealey, R.A., Cooper, I.A., Habib, M.A., 1996. Using Project Finance to Fund Infrastructure Investments. J. Appl. Corp. Finance 9, 25–39. doi:10.1111/j.1745-6622.1996.tb00296.x

Breschi, S., Malerba, F., 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. Syst. Innov. Technol. Inst. Organ. 130–156.

Breschi, S., Malerba, F., Orsenigo, L., 2000. Technological Regimes and Schumpeterian Patterns of Innovation. Econ. J. 110, 388–410. doi:10.1111/1468-0297.00530

British Petroleum, 2015. BP statistical review of world energy.

Bruton, H.J., 1998. A Reconsideration of Import Substitution. J. Econ. Lit. 36, 903–936.

Bunge, M., 2003. Emergence and convergence qualitative novelty and the unity of knowledge. University of Toronto Press, Toronto, Ont.

Busse, M., Hefeker, C., 2007. Political risk, institutions and foreign direct investment. Eur. J. Polit. Econ. 23, 397–415.

CADE, 2011. Informe de la Comisión Asesora para el Desarrollo Eléctrico (CADE). CADE.

Carlsson, B., 2006. Internationalization of innovation systems: A survey of the literature. Res. Policy 35, 56–67. doi:10.1016/j.respol.2005.08.003

Cassiolato, J.E., Baptista, M.A.C., 1996. The effects of the Brazilian liberalisation of the IT industry on technological capabilities of local firms. Inf. Technol. Dev. 7, 53–73. doi:10.1080/02681102.1996.9525270

Casson, M., 1982. The Entrepreneur: An Economic Theory. Rowman & Littlefield.

Cattaneo, O., Gereffi, G., Miroudot, S., Taglioni, D., 2013. Joining, Upgrading and Being Competitive in Global Value Chains: A Strategic Framework (SSRN Scholarly Paper No. ID 2248476). Social Science Research Network, Rochester, NY.

CCTP, 2011. Chile Necesita Una Gran Reforma Energetica - Propuestas de la CCTP Para la Transicion Hacia un Desarrollo Electrico Limpio, Seguro, Sustentable y Justo. CCTP.

Chadwick, B.P., 2006. Transaction costs and the clean development mechanism, in: Natural Resources Forum. Wiley Online Library, pp. 256–271.

Chamy, R., 2007. Potencial de Biogas - Identificacion y Clasificacion de los Distintos Tipos de Biomasa Disponibles en Chile Para la Generacion de Biogas. CNE/GTZ.

Chandler, A.D., 1991. The functions of the HQ unit in the multibusiness firm. Strateg. Manag. J. 12, 31–50. doi:10.1002/smj.4250121004

Chandler, A.D., Hikino, T., 1994. Scale and scope the dynamics of industrial capitalism. Belknap Press of Harvard University Press, Cambridge, Mass.

Chang, H.-J., 2010. How to "do"a developmental state: political, organisational and human resource requirements for the developmental state. Constr. Democr. Dev. State South Afr. Potentials Chall. 82–96.

Chang, H.-J., 2003. Kicking Away the Ladder: Infant Industry Promotion in Historical Perspective. Oxf. Dev. Stud. 31, 21–32. doi:10.1080/1360081032000047168

Chang, H.-J., 2002. Kicking Away the Ladder: Development Strategy in Historical Perspective: Policies and Institutions for Economic Development in Historical Perspective. Anthem Press, London.

Chang, H.-J., 1994. State, institutions and structural change. Struct. Change Econ. Dyn. 5, 293–313. doi:10.1016/0954-349X(94)90006-X

Cheng, S., Stough, R.R., 2006. Location decisions of Japanese new manufacturing plants in China: a discrete-choice analysis. Ann. Reg. Sci. 40, 369–387. doi:10.1007/s00168-005-0052-4

CHILE SUSTENTABLE, 2011. Analisis de Barreras para el Desarrollo de Energias Renovables No Convencionales.

Cho, Y., Newhouse, D., 2013. How Did the Great Recession Affect Different Types of Workers? Evidence from 17 Middle-Income Countries. World Dev. 41, 31–50. doi:10.1016/j.worlddev.2012.06.003

Christensen, 1997. The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business Press.

CIFES, 2016. Reporte CIFES - Marzo 2016. CORFO.

Cimoli, M., Dosi, G., Stiglitz, J.E., 2009. Industrial policy and development: the political economy of capabilities accumulation. Oxford University Press, Oxford; Toronto.

Cimoli, M., Porcile, G., 2013. Micro-Macro Interactions in Technological Learning and Growth, in: Dutrénit, G., Lee, K., Nelson, R., Vera-Cruz, A.O., Soete, L. (Eds.), Learning, Capability Building and Innovation for Development, EADI Global Development. Palgrave Macmillan UK, pp. 160–175.

Clark, C., 1940. The conditions of economic progress. Cond. Econ. Prog.

Cohen, W.M., Levin, R.C., others, 1989. Empirical studies of innovation and market structure. Handb. Ind. Organ. 2, 1059–1107.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. Adm. Sci. Q. 35, 128–152.

CORFO, 2010. Programa de energias renovables no convencionales y cambio climatico CORFO.

CORFO, 2009. Ficha Proyecto: MISION TECNOLOGICA BIOGAS Y SUSTENTABILIDAD ENERGETICA ESTADOS UNIDOS 2009.

Cowan, R., David, P.A., Foray, D., 2000. The explicit economics of knowledge codification and tacitness. Ind. Corp. Change 9, 211–253. doi:10.1093/icc/9.2.211

Crespo, N., Fontoura, M.P., 2007. Determinant factors of FDI spillovers–what do we really know? World Dev. 35, 410–425.

David, P.A., 2005. Path dependence, its critics and the quest for "historical economics" (Economic History No. 502003). EconWPA.

Davies, A., Brady, T., 2006. Charting a Path Toward Integrated Solutions. MIT Sloan Manag. Rev. 47, 39–48.

Davies, A., Brady, T., Hobday, M., 2007. Organizing for solutions: Systems seller vs. systems integrator. Ind. Mark. Manag., Project Marketing and the Marketing of Solutions 36, 183–193. doi:10.1016/j.indmarman.2006.04.009

del Favero, G., 1994. Ley sobre Bases Generales del medio Ambiente.

Di Stefano, G., Gambardella, A., Verona, G., 2012. Technology push and demand pull perspectives in innovation studies: Current findings and future research directions. Res. Policy 41, 1283–1295. doi:10.1016/j.respol.2012.03.021

Diaz, D., 2010. Oportunidades de Inversion en la Industria de las ERNC (INVESTCHILE/CORFO).

DIPRES, 2005. Programa de Electrificacion Rural - Sintesis Ejecutiva. DIPRES.

Dosi, G., 1982a. Technological paradigms and technological trajectories. Res. Policy 11, 147–162. doi:10.1016/0048-7333(82)90016-6

Dosi, G., 1982b. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. Res. Policy 11, 147–162. doi:10.1016/0048-7333(82)90016-6

Dosi, G., Nelson, R.R., Winter, S.G., 2001. The Nature and Dynamics of Organizational Capabilities. Oxford University Press, Oxford.

Dutrénit, G., 2000. Learning and knowledge management in the firm: from knowledge accumulation to strategic capabilities. Edward Elgar Publishing.

Dutrénit, G., Lee, K., Nelson, R., Soete, L., Vera-Cruz, A., 2013. Learning, Capability Building and Innovation for Development. Palgrave Macmillan.

Easterly, W., 2006. Reliving the 1950s: the big push, poverty traps, and takeoffs in economic development. J. Econ. Growth 11, 289–318. doi:10.1007/s10887-006-9006-7

Echevarria, C., 1997. Changes in sectoral composition associated with economic growth. Int. Econ. Rev. 431–452.

Elgueta, H., 2012. Attitudes to Hydroelectricity in Chile: The Roles of Trust & Social Identities (SSRN Scholarly Paper No. ID 2133335). Social Science Research Network, Rochester, NY.

Ende, J. van den, Dolfsma, W., 2005. Technology-push, demand-pull and the shaping of technological paradigms - Patterns in the development of computing technology. J. Evol. Econ. 15, 83–99. doi:10.1007/s00191-004-0220-1

Engel, 2014. The Economics of Public-Private Partnerships: A Basic Guide. Cambridge University Press, New York, NY.

Engel, E., 1857. Die productions und consumtionsverhaltnisse des konigsreichs sachsen. Zietscrift Statischen Bur. Koniglich Sachischen Minist. Inn. 3.

Engel, E., Fischer, R., Galetovic, A., 2001. El programa chileno de concesiones de infraestructura: evaluación, experiencias y perspectivas. Transform. Económica Chile.

EPA, 2013. Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management.

Esty, B., 2014. An Overview of Project Finance and Infrastructure Finance-2014 Update. HBS Case.

EVALUESERVE, 2009. Consultoria Estrategica en Promocion de Chile como Asentamiento para la Industria de Servicios Conexos de las ERNC - Informe Final. CORFO.

Evans, P.B., 1979. Dependent Development: The Alliance of Multinational, State, and Local Capital in Brazil. Princeton University Press.

Fagerberg, J., 2000. Technological progress, structural change and productivity growth: a comparative study. Struct. Change Econ. Dyn. 11, 393–411. doi:10.1016/S0954-349X(00)00025-4

Fagerberg, J., 1987. A technology gap approach to why growth rates differ. Res. Policy 16, 87–99. doi:10.1016/0048-7333(87)90025-4

Fagerberg, J., Godinho, M.M., others, 2005. Innovation and catching-up. Oxf. Handb. Innov. Oxf. Univ. Press N. Y. 514–543.

Figueiredo, P.N., 2003. Learning, capability accumulation and firms differences: evidence from latecomer steel. Ind. Corp. Change 12, 607–643.

Figueiredo, P.N., 2002. Does technological learning pay off? Inter-firm differences in technological capability-accumulation paths and operational performance improvement. Res. Policy 31, 73–94. doi:10.1016/S0048-7333(01)00106-8

Fisher, A.G., 1939. Production, primary, secondary and tertiary. Econ. Rec. 15, 24–38.

Fourastié, J., 1954. Die gro\s se Hoffnung des 20. Jhd. Bund-Verl.

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson, D., 2005. UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. Energy Policy 33, 2123–2137. doi:10.1016/j.enpol.2004.04.011

Freeman, C., 2002. Continental, national and sub-national innovation systems—complementarity and economic growth. Res. Policy, Innovation Systems 31, 191–211. doi:10.1016/S0048-7333(01)00136-6

Freeman, C., 1995. The "National System of Innovation" in historical perspective. Camb. J. Econ. 19, 5–24.

Freeman, C., 1987. Technology policy and economic performance: lessons from Japan.

Freeman, C., Louçã, F., 2002. As Time Goes By: From the Industrial Revolutions to the Information Revolution. Oxford University Press, USA.

Freeman, C., Perez, C., 1988. Structural crises of adjustment, business cycles and investment behaviour. Pinter.

Friedman, T.L., 2007. The World is Flat: The Globalized World in the Twenty-first Century, 2Rev Ed edition. ed. Penguin, London.

Fu, X., 2008. Foreign direct investment, absorptive capacity and regional innovation capabilities: evidence from China. Oxf. Dev. Stud. 36, 89–110.

Furtado, C., Iglésias, F., 1959. Formação econômica do Brasil.

GAMMA INGENIEROS, 2011. Modelos de Negocio que Rentabilicen Aplicaciones de Biogas en Chile y su Fomento. MinEnergia.

Geels, D.I.F.W., 2005. The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technol. Anal. Strateg. Manag. 17, 445–476. doi:10.1080/09537320500357319

Geels, F., Raven, R., 2006. Non-linearity and Expectations in Niche-Development Trajectories: Ups and Downs in Dutch Biogas Development (1973–2003). Technol. Anal. Strateg. Manag. 18, 375–392. doi:10.1080/09537320600777143

Geels, F.W., 2012. A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. J. Transp. Geogr., Special Section on Theoretical Perspectives on Climate Change Mitigation in Transport 24, 471–482. doi:10.1016/j.jtrangeo.2012.01.021

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Policy, NELSON + WINTER + 20 31, 1257–1274. doi:10.1016/S0048-7333(02)00062-8

Gerard, D., Lave, L., 2007. Experiments in technology forcing: comparing the regulatory processes of US automobile safety and emissions regulations. Int. J. Technol. Policy Manag. 7, 1–14.

Gerard, D., Lave, L.B., 2005. Implementing technology-forcing policies: The 1970 Clean Air Act Amendments and the introduction of advanced automotive emissions controls in the United States. Technol. Forecast. Soc. Change 72, 761–778. doi:10.1016/j.techfore.2004.08.003

Gereffi, G., Humphrey, J., Sturgeon, T., 2005. The governance of global value chains. Rev. Int. Polit. Econ. 12, 78–104. doi:10.1080/09692290500049805

Gereffi, G., Korzeniewicz, M., 1994. Commodity Chains and Global Capitalism. ABC-CLIO.

Geroski, P.A., Jacquemin, A., 1988. The persistence of profits: a European comparison. Econ. J. 98, 375–389.

Gerschenkron, A., 1962. Economic backwardness in historical perspective. 456 pp.

Giuliani, E., Pietrobelli, C., Rabellotti, R., 2005. Upgrading in global value chains: lessons from Latin American clusters. World Dev. 33, 549–573.

GIZ, 2015. Herramienta de software para análisis de rentabilidad de inversiones en proyectos de energía renovable y eficiencia energética: Manual del Usuario.

Gomá, Ó.M., 2009. Desarrollo productivo en Chile: la experiencia de Corfo entre 1990 y 2009. CORFO.

Gómez-Ibáñez, J.A., 2009. Regulating infrastructure: monopoly, contracts, and discretion. Harvard University Press.

Greenwald, B.C., Stiglitz, J.E., 1986. Externalities in Economies with Imperfect Information and Incomplete Markets. Q. J. Econ. 101, 229–264. doi:10.2307/1891114

Griliches, Z., 1991. The Search for R&D Spillovers (Working Paper No. 3768). National Bureau of Economic Research.

Gruss, B., 2014. After the Boom–Commodity Prices and Economic Growth in Latin America and the Caribbean. International Monetary Fund.

Hall, P.A., Soskice, D., 2001. Varieties of capitalism: The institutional foundations of comparative advantage. OUP Oxford.

Harberger, A.C., 1998. A vision of the growth process. Am. Econ. Rev. 88, 1–32.

Hausmann, R., Hidalgo, C., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., Yildirim, M., 2011. The atlas of economic complexity. Boston USA.

Hausmann, R., Hwang, J., Rodrik, D., 2007. What you export matters. J. Econ. Growth 12, 1–25.

Hausmann, R., Klinger, B., 2007a. The structure of the product space and the evolution of comparative advantage.

Hausmann, R., Klinger, B., 2007b. Structural transformation in Chile. Quantum Advis. Group.

Hausmann, R., Rodrik, D., 2003. Economic development as self-discovery. J. Dev. Econ. 72, 603–633.

Hausmann, R., Rodrik, D., Velasco, A., 2008. Growth diagnostics. Wash. Consens. Reconsidered New Glob. Gov. 324–355.

Henderson, V., 1997. Externalities and Industrial Development. J. Urban Econ. 42, 449–470. doi:10.1006/juec.1997.2036

Hentzschel, F., Flores, P., 2011. Impacto de la Ley Arica sobre el Desarrollo de una Industria Solar en Chile. CORFO.

Herrera, R., E, S., Torrent, R., Carlos, J., 2015. Proyecto Hidroaysén: capitalismo extractivista, regulación estatal y acción colectiva en la Patagonia. Polis Santiago 14, 439–467. doi:10.4067/S0718-65682015000100021

Hidalgo, C.A., Hausmann, R., 2009. The building blocks of economic complexity. Proc. Natl. Acad. Sci. 106, 10570–10575. doi:10.1073/pnas.0900943106

Hidalgo, C.A., Hausmann, R., 2008. A network view of economic development. Dev. Altern. 12, 5–10.

Hidalgo, C.A., Klinger, B., Barabási, A.-L., Hausmann, R., 2007. The Product Space Conditions the Development of Nations. Science 317, 482–487. doi:10.1126/science.1144581

Hirschman, 1970. Exit, Voice and Loyalty: Responses to Decline in Firms, Organizations and States, New Ed edition. ed. Harvard University Press, Cambridge, Mass.

Hirschman, A.O., 1981. Essays in Trespassing (Cambridge Books). Cambridge University Press.

Hirschman, A.O., 1968. The Political Economy of Import-Substituting Industrialization in Latin America. Q. J. Econ. 82, 1–32. doi:10.2307/1882243

Hirschman, A.O., 1958. The strategy of economic development. Yale University Press (New Haven).

Hobday, M., 2000. The project-based organisation: an ideal form for managing complex products and systems? Res. Policy 29, 871–893. doi:10.1016/S0048-7333(00)00110-4

Hobday, M., 1998. Product complexity, innovation and industrial organisation. Res. Policy 26, 689–710. doi:10.1016/S0048-7333(97)00044-9

Hobday, M., 1995. Innovation in East Asia: The Challenge to Japan. Edward Elgar Pub.

Hobday, M., Rush, H., 2007. Upgrading the technological capabilities of foreign transnational subsidiaries in developing countries: The case of electronics in Thailand. Res. Policy 36, 1335–1356. doi:10.1016/j.respol.2007.05.004

Hobsbawm, E.J., 1999. Industry and Empire: from 1750 to the Present Day. The New Press.

Horvath, M., Schivardi, F., Woywode, M., 2001. On industry life-cycles: delay, entry, and shakeout in beer brewing. Int. J. Ind. Organ. 19, 1023–1052.

Huneeus, C., 2007. Argentina y Chile: el conflicto del gas, factores de política interna Argentina / Argentine domestic policy and the conflict over gas exports to Chile. Estud. Int. 40, 179–212.

Iammarino, S., McCann, P., 2006. The structure and evolution of industrial clusters: Transactions, technology and knowledge spillovers. Res. Policy 35, 1018–1036. doi:10.1016/j.respol.2006.05.004

Iammarino, S., Padilla-Pérez, R., von Tunzelmann, N., 2008. Technological Capabilities and Global–Local Interactions: The Electronics Industry in Two Mexican Regions. World Dev., Special Section (pp. 2045-2102). The Volatility of Overseas Aid 36, 1980–2003. doi:10.1016/j.worlddev.2007.10.022

IEA, 2015. World Energy Outlook 2015.

IEA, 2012. IEA Statistics - Electricity Information - 2012.

IEA, 2011. Technology Roadmap: Smart Grids.

Ijiri, Y., Simon, H.A., 1964. Business Firm Growth and Size. Am. Econ. Rev. 54, 77–89.

INODU, 2014. Utilizacion de bloques horarios en licitación de suministro a distribuidoras: caso licitación SIC 2013/03 - 2º llamado. ACERA.

IOM, 2015. World Migration Report 2015 – Migrants and Cities: New Partnerships to Manage Mobility.

IPCC, 2015. IPCC Fifth Assessment Synthesis Report.

IRENA, 2015. Renewable Power Generation Costs in 2014.

IRENA, 2012. Renewable Energy Technology: Cost Analysis Series. Volume 1: Power Sector. Issue 4/5. Solar Photovoltaics.

Jacquemin, A., others, 1987. The new industrial organization: Market forces and strategic behavior. MIT Press Books 1.

Jaffe, A.B., 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value. National Bureau of Economic Research Cambridge, Mass., USA.

Jaumotte, M.F., 2004. Foreign Direct Investment and Regional Trade Agreements: The Market Size Effect Revisited. International Monetary Fund.

Johnson, B., Lorenz, E., Lundvall, B.-\AAke, 2002. Why all this fuss about codified and tacit knowledge? Ind. Corp. Change 11, 245–262.

Joskow, P.L., Schmalensee, R., 1983. Markets for power: an analysis of electric utility deregulation.

Katz, J., 2001. Structural reforms and technological behaviour: The sources and nature of technological change in Latin America in the 1990s. Res. Policy 30, 1–19. doi:10.1016/S0048-7333(99)00099-2

Katz, J., 1997. Historia evolutiva de una planta metalmecánica chilena.

Katz, J.M., 1984. Domestic technological innovations and dynamic comparative advantage: Further reflections on a comparative case-study program. J. Dev. Econ. 16, 13–37. doi:10.1016/0304-3878(84)90100-7

Katz, J.M., 1976. Importación de tecnología, aprendizaje e industrialización dependiente.

Katz, M.L., Shapiro, C., 1994. Systems Competition and Network Effects. J. Econ. Perspect. 8, 93–115.

Kelegama, S., Foley, F., 1999. Impediments to Promoting Backward Linkages from the Garment Industry in Sri Lanka. World Dev. 27, 1445–1460. doi:10.1016/S0305-750X(99)00069-8

Kersan-Skabic, I., Orlic, E., 2007. Determinants of Fdi Inflows in Cee1 and Western Balkan Countries (is Accession to the Eu Important for Attracting Fdi?). Econ. Bus. Rev. Cent. South - East. Eur. 9, 333-350-365.

Khatib, H., 2003. Economic Evaluation of Projects in the Electricity Supply Industry, Revised Edition. IET.

Kim, L., 1997. Imitation to Innovation: The Dynamics of Korea's Technological Learning. Harvard Business Review Press, Boston.

Kirzner, I.M., 1999. Creativity and/or alertness: A reconsideration of the Schumpeterian entrepreneur. Rev. Austrian Econ. 11, 5–17.

Kirzner, I.M., 1997. Entrepreneurial discovery and the competitive market process: An Austrian approach. J. Econ. Lit. 35, 60–85.

Klepper, S., 2010. The origin and growth of industry clusters: The making of Silicon Valley and Detroit. J. Urban Econ. 67, 15–32.

Klepper, S., 1997. Industry Life Cycles. Ind. Corp. Change 6, 145–182. doi:10.1093/icc/6.1.145

Klepper, S., Graddy, E., 1990. The Evolution of New Industries and the Determinants of Market Structure. RAND J. Econ. 21, 27–44. doi:10.2307/2555491

Klevorick, A.K., Levin, R.C., Nelson, R.R., Winter, S.G., 1995. On the sources and significance of interindustry differences in technological opportunities. Res. Policy 24, 185–205. doi:10.1016/0048-7333(93)00762-I

Klinger, B., 2009. Is South-South trade a testing ground for structural transformation? Policy Issues Int. Trade Commod. Study Ser. 40.

Knight, F.H., 1912. Risk, uncertainty and profit. Courier Dover Publications.

Koch, N., Fuss, S., Grosjean, G., Edenhofer, O., 2014. Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything?—New evidence. Energy Policy 73, 676–685.

Kondratiev, N.D., 1925. The major economic cycles. Vopr. Konjunktury 1, 28–79.

Korotayev, A.V., Tsirel, S.V., 2010. A Spectral Analysis of World GDP Dynamics: Kondratieff Waves, Kuznets Swings, Juglar and Kitchin Cycles in Global Economic Development, and the 2008–2009 Economic Crisis. Struct. Dyn. 4.

Kost, C., Mayer, J.N., Thomsen, J., Hartmann, N., Senkpiel, C., Philipps, S., Nold, S., Lude, S., Saad, N., Schlegl, T., 2013. Levelized cost of electricity renewable energy technologies.

Krüger, J.J., 2008. Productivity and Structural Change: A Review of the Literature. J. Econ. Surv. 22, 330–363. doi:10.1111/j.1467-6419.2007.00539.x

Kuznets, S., 1973. Modern economic growth: findings and reflections. Am. Econ. Rev. 63, 247–258.

Kuznets, S.S., Murphy, J.T., 1966. Modern economic growth: Rate, structure, and spread. Yale University Press New Haven.

Lall, S., 1992. Technological capabilities and industrialization. World Dev. 20, 165–186.

Lall, S., 1980. Vertical Inter-Firm Linkages In LDCs: An Empirical Study. Oxf. Bull. Econ. Stat. 42, 203–226.

Lall, S., Narula, R., 2006. Understanding FDI-Assisted Economic Development. Routledge.

Lanz, R., Miroudot, S., Nordås, H., 2011. Trade in Tasks.

Leff, N.H., 1979. Entrepreneurship and Economic Development: The Problem Revisited. J. Econ. Lit. 17, 46–64.

Leff, N.H., 1978. Industrial Organization and Entrepreneurship in the Developing Countries: The Economic Groups. Econ. Dev. Cult. Change 26, 661–675.

Leftwich, A., 1995. Bringing politics back in: Towards a model of the developmental state. J. Dev. Stud. 31, 400–427.

Leibenstein, H., 1968. Entrepreneurship and development. Am. Econ. Rev. 72–83.

Leiner, B.M., Cerf, V.G., Clark, D.D., Kahn, R.E., Kleinrock, L., Lynch, D.C., Postel, J., Roberts, L.G., Wolff, S., 2009. A Brief History of the Internet. SIGCOMM Comput Commun Rev 39, 22–31. doi:10.1145/1629607.1629613

Leonard, D., 1992. Core capabilities and core rigidities: A paradox in managing new product development. Strateg. Manag. J. 13, 111–125.

Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Gilbert, R., Griliches, Z., 1987. Appropriating the Returns from Industrial Research and Development. Brook. Pap. Econ. Act. 1987, 783–831. doi:10.2307/2534454

Lewis, W.A., 1954. Economic Development with Unlimited Supplies of Labour. Manch. Sch. 22, 139–191. doi:10.1111/j.1467-9957.1954.tb00021.x

Liu, J., Goldstein, D., 2013. Understanding China's renewable energy technology exports. Energy Policy, Special Section: Transition Pathways to a Low Carbon Economy 52, 417–428. doi:10.1016/j.enpol.2012.09.054

Löf, G.O.G., Duffie, J.A., Smith, C.O., 1966. World distribution of solar radiation. Sol. Energy 10, 27–37. doi:10.1016/0038-092X(66)90069-7

Lucioni, L., 2009. La provisión reciente de infraestructura en América Latina: tendencias, inversiones y financiamiento. CEPAL.

Lumpkin, G.T., Dess, G.G., 1996. Clarifying the Entrepreneurial Orientation Construct and Linking It To Performance. Acad. Manage. Rev. 21, 135–172. doi:10.5465/AMR.1996.9602161568

Lundvall, B.-A., 1992. National innovation system: towards a theory of innovation and interactive learning. Pinter Lond.

Lundvall, B.-\AAke, 1992. National systems of innovation: Toward a theory of innovation and interactive learning. Anthem Press.

Mahoney, J.T., Pandian, J.R., 1992. The resource-based view within the conversation of strategic management. Strateg. Manag. J. 13, 363–380.

Malerba, F., 2007. Innovation and the evolution of industries, in: Cantner, P.D.U., Malerba, P.F. (Eds.), Innovation, Industrial Dynamics and Structural Transformation. Springer Berlin Heidelberg, pp. 7–27.

Malerba, F., 2004. Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe. Cambridge University Press.

Malerba, F., 2002. Sectoral systems of innovation and production. Res. Policy, Innovation Systems 31, 247–264. doi:10.1016/S0048-7333(01)00139-1

Malerba, F., Nelson, R., 2011. Learning and catching up in different sectoral systems: evidence from six industries. Ind. Corp. Change 20, 1645–1675. doi:10.1093/icc/dtr062

Malerba, F., Nelson, R., Orsenigo, L., Winter, S., 2007. Demand, innovation, and the dynamics of market structure: The role of experimental users and diverse preferences. J. Evol. Econ. 17, 371–399. doi:10.1007/s00191-007-0060-x

Malerba, F., Nelson, R., Orsenigo, L., Winter, S., 1999. "History-friendly" models of industry evolution: the computer industry. Ind. Corp. Change 8, 3–40. doi:10.1093/icc/8.1.3

Malerba, F., Nelson, R.R., 2012. Economic Development as a Learning Process: Variation Across Sectoral Systems. Edward Elgar Publishing.

Malerba, F., Orsenigo, L., 1996. The Dynamics and Evolution of Industries. Ind. Corp. Change 5, 51–87. doi:10.1093/icc/5.1.51

Malerba, F., Orsenigo, L., 1993. Technological Regimes and Firm Bebavior. Ind. Corp. Change 2, 45–71. doi:10.1093/icc/2.1.45

Marin, A., Bell, M., 2010. The local/global integration of MNC subsidiaries and their technological behaviour: Argentina in the late 1990s. Res. Policy 39, 919–931.

Marin, A., Bell, M., 2006. Technology spillovers from Foreign Direct Investment (FDI): the active role of MNC subsidiaries in Argentina in the 1990s. J. Dev. Stud. 42, 678–697.

Marin, A., Navas-Alemán, L., Perez, C., 2015. Natural Resource Industries As a Platform for the Development of Knowledge Intensive Industries. Tijdschr. Voor Econ. En Soc. Geogr. 106, 154–168. doi:10.1111/tesg.12136

Marin, A., Stubrin, L., van Zwanenberg, P., 2014. Developing capabilities in the seed industry: which direction to follow? [WWW Document]. URL http://www.sussex.ac.uk/spru/research/swps (accessed 12.28.15).

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. Res. Policy, Special Section on Sustainability Transitions 41, 955–967. doi:10.1016/j.respol.2012.02.013

Martin, B.R., 2010. The origins of the concept of “foresight” in science and technology: An insider’s perspective. Technol. Forecast. Soc. Change, Strategic Foresight 77, 1438–1447. doi:10.1016/j.techfore.2010.06.009

Martin, B.R., 1995. Foresight in science and technology. Technol. Anal. Strateg. Manag. 7, 139–168. doi:10.1080/09537329508524202

Martin, B.R., Johnston, R., 1999. Technology Foresight for Wiring Up the National Innovation System: Experiences in Britain, Australia, and New Zealand. Technol. Forecast. Soc. Change 60, 37–54. doi:10.1016/S0040-1625(98)00022-5

Mata-Alvarez, J., Macé, S., Llabrés, P., 2000. Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives. Bioresour. Technol. 74, 3–16. doi:10.1016/S0960-8524(00)00023-7

Mathews, J.A., 1997. A Silicon Valley of the east: Creating Taiwan’s semiconductor industry. Calif. Manage. Rev. 39, 26–54.

Mayer, J., 1996. Learning sequences and structural diversification in developing countries. J. Dev. Stud. 33, 210–229. doi:10.1080/00220389608422463

Mazzucato, M., 2013. The Entrepreneurial State: Debunking Public vs. Private Sector Myths, First Edition edition. ed. Anthem Press, London ; New York.

Mazzucato, M., Semieniuk, G., 2016. Financing Renewable Energy: Who Is Financing What and Why it Matters (SSRN Scholarly Paper No. ID 2796552). Social Science Research Network, Rochester, NY.

McKern, B., 1993. Transnational corporations and the exploitation of natural resources. Taylor & Francis.

McMillan, M.S., Rodrik, D., 2011. Globalization, structural change and productivity growth. National Bureau of Economic Research.

Metcalfe, J.S., Foster, J., Ramlogan, R., 2006. Adaptive economic growth. Camb. J. Econ. 30, 7–32.

Michaelowa, A., Jotzo, F., 2005. Transaction costs, institutional rigidities and the size of the clean development mechanism. Energy Policy 33, 511–523.

MinBienesNacionales, 2013. Orden Ministerial N° 6 - Imparte norma en Materia de Concesiones de Inm Fiscales para Proyectos Energia Renovable.

MINENERGIA/GIZ, 2012a. Las Energías Renovables no Convencionales en el Mercado Eléctrico Chileno (Documento Complementario). MinEnergia/GIZ.

MINENERGIA/GIZ, 2012b. Explorador del Recurso Solar de Chile - Documentacion y Manual de Uso. MINENERGIA/GIZ.

MINENERGIA/GIZ, 2009. Las Energías Renovables no Convencionales en el Mercado Eléctrico Chileno. CNE/GIZ.

MINENERGIA/GIZ, 2007a. Proyectos de Biomasa - Guía Para Evaluación Ambiental. MinEnergia/GIZ.

MINENERGIA/GIZ, 2007b. Proyectos Eólicos - Guía Para Evaluación Ambiental. MinEnergia/GIZ.

Ministerio de Energia, 2015. Energia 2050 - Politica Energetica de Chile.

Miozzo, M., Soete, L., 2001. Internationalization of Services: A Technological Perspective. Technol. Forecast. Soc. Change 67, 159–185. doi:10.1016/S0040-1625(00)00091-3

Montobbio, F., 2002. An evolutionary model of industrial growth and structural change. Struct. Change Econ. Dyn. 13, 387–414. doi:10.1016/S0954-349X(02)00006-1

Moreno, J., Morcaquer, S., Rudnick, H., 2006. Generación Eólica en Chile: Análisis del Entorno y Perspectivas de Desarrollo.

Moreno, R., Barroso, L.A., Rudnick, H., Mocarquer, S., Bezerra, B., 2010. Auction approaches of long-term contracts to ensure generation investment in electricity markets: Lessons from the Brazilian and Chilean experiences. Energy Policy, The socio-economic transition towards a hydrogen economy - findings from European research, with regular papers 38, 5758–5769. doi:10.1016/j.enpol.2010.05.026

Moretti, E., 2004. Chapter 51 - Human Capital Externalities in Cities, in: Thisse, J.V.H. and J.-F. (Ed.), Handbook of Regional and Urban Economics, Cities and Geography. Elsevier, pp. 2243–2291.

Morris, M., Kaplinsky, R., Kaplan, D., 2012. One Thing Leads to Another: Promoting Industrialisation by Making the Most of the Commodity Boom in Sub-Saharan Africa. Lulu Enterprises Incorporated.

Moss, T., Marvin, S., 2016. Urban Infrastructure in Transition: Networks, Buildings and Plans. Routledge.

Mowery, D.C., 1983. Economic theory and government technology policy. Policy Sci. 16, 27–43.

Muga, H.E., Mihelcic, J.R., 2008. Sustainability of wastewater treatment technologies. J. Environ. Manage. 88, 437–447. doi:10.1016/j.jenvman.2007.03.008

Murphy, K.M., Shleifer, A., Vishny, R.W., 1988. Industrialization and the Big Push (Working Paper No. 2708). National Bureau of Economic Research.

Nasirov, S., Silva, C., Agostini, C.A., 2015. Investors' Perspectives on Barriers to the Deployment of Renewable Energy Sources in Chile. Energies 8, 3794–3814. doi:10.3390/en8053794

Navarro, P., Titelman, E., Twyman, C., 2005. Programa de Electrificacion Rural - Informe Final. MinInterior/CNE/SUBDERE.

Neffke, F., Hartog, M., Boschma, R., Henning, M., 2014. Agents of structural change. The role of firms and entrepreneurs in regional diversification (Papers in Evolutionary Economic Geography (PEEG) No. 1410). Utrecht University, Section of Economic Geography.

Neffke, F., Henning, M., Boschma, R., 2011. How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. Econ. Geogr. 87, 237–265. doi:10.1111/j.1944-8287.2011.01121.x

Nelson, R., 1993. National innovation systems: a comparative analysis.

Nelson, R.R., 1991. Why do firms differ, and how does it matter? Strateg. Manag. J. 12, 61–74.

Nelson, R.R., Winter, S.G., 2002. Evolutionary Theorizing in Economics. J. Econ. Perspect. 16, 23–46. doi:10.2307/2696495

Nelson, R.R., Winter, S.G., 1982. An evolutionary theory of economic change [...] [...]. Belknap Press of Harvard Univ. Press, Cambridge, Mass. [u.a.

Nelson, R.R., Winter, S.G., 1977. In search of useful theory of innovation. Res. Policy 6, 36–76. doi:10.1016/0048-7333(77)90029-4

Nemet, G.F., 2009. Demand-pull, technology-push, and government-led incentives for non-incremental technical change. Res. Policy 38, 700–709. doi:10.1016/j.respol.2009.01.004

Nieto, M., Quevedo, P., 2005. Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort. Technovation 25, 1141–1157. doi:10.1016/j.technovation.2004.05.001

Nightingale, P., Coad, A., 2013. Muppets and gazelles: political and methodological biases in entrepreneurship research. Ind. Corp. Change dtt057. doi:10.1093/icc/dtt057

Noorbakhsh, F., Paloni, A., Youssef, A., 2001. Human Capital and FDI Inflows to Developing Countries: New Empirical Evidence. World Dev. 29, 1593–1610. doi:10.1016/S0305-750X(01)00054-7

Ocampo, J.A., 2010. How well has Latin America fared during the global financial crisis?

Ocampo, J.A., 2009. Latin America and the global financial crisis. Camb. J. Econ. 33, 703–724. doi:10.1093/cje/bep030

O'Donovan, C., 2016. emergence of innovation systemsin new locations: theoretical explorations and an in-depth case study ofwind energy technologies in Ireland, 1990-2014 (PhD). University of Sussex.

OECD, 2007. Infrastructure to 2030, Volume 2: Mapping Policy for Electricity, Water and Transport.

OECD, 2006. Infrastructure to 2030: Telecom, Land Transport, Water and Electricity.

Olivares, A., Maldonado, P., 2012. Reporte CER, Diciembre 2012. Centro de Energias Renovables, CORFO, Ministerio de Economia y Turismo de Chile.

Ortega, L., 1989. CORFO - 50 Años de Realizaciones - 1939-1989.

Ortegón, E., 2007. Manual de prospectiva y decisión estratégica: bases teóricas e instrumentos para América Latina y el Caribe. United Nations Publications.

Pasinetti, L.L., 1983. Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations. CUP Archive.

Patel, P., Pavitt, K., 1991. Europe's technological performance. University of Sussex, Science Policy Research Unit.

Pavitt, K., 1984. Sectoral patterns of technical change: Towards a taxonomy and a theory. Res. Policy 13, 343–373. doi:10.1016/0048-7333(84)90018-0

Penrose, E., 1959. The Theory of the Growth of the Firm, 4th ed. OUP Oxford.

Perez, C., 2013. Unleashing a golden age after the financial collapse: Drawing lessons from history. Environ. Innov. Soc. Transit., Economic-financial crisis and sustainability transition 6, 9–23. doi:10.1016/j.eist.2012.12.004

Perez, C., 2010. Technological revolutions and techno-economic paradigms. Camb. J. Econ. 34, 185–202. doi:10.1093/cje/bep051

Perez, C., 2003. Technological revolutions and financial capital. Edward Elgar Publishing.

Perez, C., 1999. Technological change and opportunities for development as a moving target.

Perez, C., 1996. La modernization industrial en America Latina y la herencia de la sustitucion de importaciones. Comer. Exter. 46.

Perez, C., 1983. Structural change and assimilation of new technologies in the economic and social systems. Futures 15, 357–375. doi:10.1016/0016-3287(83)90050-2

Perez, C., Soete, L., 1988. Catching up in technology: entry barriers and windows of opportunity. Tech. Change Econ. Theory 458–479.

Peters, M., Schneider, M., Griesshaber, T., Hoffmann, V.H., 2012. The impact of technology-push and demand-pull policies on technical change – Does the locus of policies matter? Res. Policy 41, 1296–1308. doi:10.1016/j.respol.2012.02.004

Pinto, A., 1973. Chile, un caso de desarrollo frustrado. Tercera edición. Editorial universitaria.

Pissarides, C.A., 2013. Unemployment in the Great Recession. Economica 80, 385–403. doi:10.1111/ecca.12026

Polanyi, M., 1967. The tacit dimension.

Prebisch, R., 1950. El desarrollo económico de la América Latina y algunos de sus principales problemas. Desarrollo Económico. doi:10.2307/3466824

Reitz, J.G., 2005. Tapping Immigrants' Skills: New Directions for Canadian Immigration Policy in the Knowledge Economy Symposium: North American Migration, Trade and Security. Law Bus. Rev. Am. 11, 409–432.

Rennkamp, B., Westin, F.F., 2013. Feito no Brasil? Made in South Africa? Boosting technological development through local content requirements in the wind energy industry. Energy Res. Cent.

Rivas, G., 2012. La experiencia de CORFO y la transformación productiva de Chile - evolucion, aprendizaje y lecciones de desarrollo. BANCO Desarro. AMÉRICA Lat. Ser. POLÍTICAS PÚBLICAS Transform. Product.

Robertson, T.S., 1967. The Process of Innovation and the Diffusion of Innovation. J. Mark. 31, 14–19. doi:10.2307/1249295

Rodriguez, H., 2012. Programa Remocion de Barreras para la Electrificacion Rural con Energias Renovables - Evaluacion Final Externa. MinEnergia/UNDP/GEF.

Rodriguez-Clare, A., 1996. Multinationals, linkages, and economic development. Am. Econ. Rev. 852–873.

Rodrik, D., 2010. Diagnostics before Prescription. J. Econ. Perspect. 24, 33–44.

Romeu, G., 2014. El mercado de tratamiento de aguas en Chile (Diciembre 2014).

Rosenberg, N., 1994. Exploring the Black Box: Technology, Economics, and History. Cambridge University Press.

Rosenberg, N., 1990. Why do firms do basic research (with their own money)? Res. Policy 19, 165–174.

Rosende, D., 2010. Gestion Experta Global Para Atraccion de Inversiones en la Industria Auxiliar de ERNC (POCH).

Rosenstein-Rodan, P.N., 1943. Problems of industrialisation of eastern and south-eastern Europe. Econ. J. 202–211.

Rudnick, H., Mocarquer, S., 2006. Contract auctions to assure supply adequacy in an uncertain energy environment, in: IEEE Power Engineering Society General Meeting, 2006. Presented at the IEEE Power Engineering Society General Meeting, 2006, p. 4 pp.-pp. doi:10.1109/PES.2006.1709563

Sabbatella, I., 2015. Radiografía del sector de hidrocarburos [WWW Document]. Rev. CCC En Línea Enero Junio 2015 N° 22. URL http://www.centrocultural.coop/revista/articulo/537/unasur_radiografia_del_sector_de_hidrocarburos.html (accessed 11.18.16).

Salter, W.E.G., 1960. Productivity & Technical Change, ; University of Cambridge Department of Applied Economics Monograph 6. Cambridge: Cambridge University Press.

Sánchez, R.J., Wilmsmeier, G., 2005. Provisión de infraestructura de transporte en América Latina: experiencia reciente y problemas observados. United Nations Publications.

Santana, C., 2014. Energias Renovables en Chile - El potencial eolico, solar e hidroelectrico de Arica a Chiloe. MinEnergia/GIZ.

Saviotti, P.P., Pyka, A., 2004. Economic development, qualitative change and employment creation. Struct. Change Econ. Dyn. 15, 265–287.

Schneider, B.R., 2013. Hierarchical Capitalism in Latin America: Business, Labor, and the Challenges of Equitable Development. Cambridge University Press.

Schumpeter, J., 1942. Capitalism, Socialism and Democracy.

Schumpeter, J.A., 1939. Business Cycles: A theoretical, historical and statistical analysis of the Capitalist process.

Schumpeter, J.A., 1912. The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers.

Shane, S., Venkataraman, S., 2000. The Promise of Entrepreneurship as a Field of Research. Acad. Manage. Rev. 25, 217–226. doi:10.5465/AMR.2000.2791611

Shy, O., 1996. Technology revolutions in the presence of network externalities. Int. J. Ind. Organ. 14, 785–800.

Silva, E.G., Teixeira, A.A., 2008. Surveying structural change: Seminal contributions and a bibliometric account. Struct. Change Econ. Dyn. 19, 273–300.

Silverberg, G., Verspagen, B., 2003. Breaking the waves: a Poisson regression approach to Schumpeterian clustering of basic innovations. Camb. J. Econ. 27, 671–693. doi:10.1093/cje/27.5.671

Simon, H.A., Bonini, C.P., 1958. The Size Distribution of Business Firms. Am. Econ. Rev. 48, 607–617.

Smith, A., Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Res. Policy, Special Section on Innovation and Sustainability Transitions 39, 435–448. doi:10.1016/j.respol.2010.01.023

Soete, L., 1985. International diffusion of technology, industrial development and technological leapfrogging. World Dev. 13, 409–422. doi:10.1016/0305-750X(85)90138-X

Sohr, R., 2012. Chile a ciegas: La triste realidad de nuestro modelo energético. Penguin Random House Grupo Editorial Chile.

Solow, R.M., 1956. A Contribution to the Theory of Economic Growth. Q. J. Econ. 70, 65–94. doi:10.2307/1884513

Steinmueller, W.E., 2001. ICTs and the possibilities for leapfrogging by developing countries. Int. Labour Rev. 140, 193–210. doi:10.1111/j.1564-913X.2001.tb00220.x

Stiglitz, J., 2007. Making Globalization Work: The Next Steps to Global Justice, 1st Thus edition. ed. Penguin, London.

Sutton, J., 2005. Competing in capabilities: an informal overview. Lond. Lond. Sch. Econ.

Sutton, J., 1991. Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration. MIT Press.

Sydow, J., Lindkvist, L., DeFillippi, R., 2004. Project-based organizations, embeddedness and repositories of knowledge: Editorial. Organ. Stud.-Berl.-Eur. GROUP Organ. Stud.- 25, 1475.

Taylor, M., 2008. Beyond technology-push and demand-pull: Lessons from California's solar policy. Energy Econ., Technological Change and the Environment 30, 2829–2854. doi:10.1016/j.eneco.2008.06.004

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strateg. Manag. J. 18, 509–533.

Thompson, P., 2010. Learning by doing. Handb. Econ. Innov. 1, 429–476.

Todaro, M.P., 2014. Economic Development, 12th edition, 12 edition. ed. Trans-Atlantic Publications, Harlow u.a.

Train, K.E., others, 1991. Optimal regulation: the economic theory of natural monopoly. MIT Press Books 1.

UNEP/ISWA, 2015. Global Waste Management Outlook.

United Nations, 2008. International Standard Industrial Classification of All Economic Activities (ISIC), Rev. 4. U. N. Stat. Pap.

UN-WATER, 2014. Investing in Water and Sanitation Increasing Access, Reducing Inequalities.

Utterback, J.M., Abernathy, W.J., 1975. A dynamic model of process and product innovation. Omega 3, 639–656.

Utterback, J.M., Suárez, F.F., 1993. Innovation, competition, and industry structure. Res. Policy 22, 1–21. doi:10.1016/0048-7333(93)90030-L

Van Audenhove, F.-J., Korniichuk, O., Dauby, L., Pourbaix, J., 2014. The Future of Urban Mobility 2.0 - Imperatives to shape extended mobility ecosystems of tomorrow.

Van Dijk, M., Bell, M., 2007. Rapid Growth with Limited Learning: Industrial Policy and Indonesia's Pulp and Paper Industry. Oxf. Dev. Stud. 35, 149–169. doi:10.1080/13600810701322017

Verbong, G.P.J., Geels, F.W., 2010. Exploring sustainability transitions in the electricity sector with socio-technical pathways. Technol. Forecast. Soc. Change, Issue includes a Special Section on "Infrastructures and Transitions" 77, 1214–1221. doi:10.1016/j.techfore.2010.04.008

Verspagen, B., 1991. A new empirical approach to catching up or falling behind. Struct. Change Econ. Dyn. 2, 359–380.

Vince, G., 2010. Dams for Patagonia. Science 329, 382–385. doi:10.1126/science.329.5990.382

Wallerstein, I., 1979. The Capitalist World-Economy. Cambridge University Press.

Williamson, O.E., 2000. The new institutional economics: taking stock, looking ahead. J. Econ. Lit. 595–613.

Williamson, O.E., 1999. Strategy research: governance and competence perspectives.

Williamson, O.E., 1981. The Economics of Organization: The Transaction Cost Approach. Am. J. Sociol. 87, 548–577.

Williamson, O.E., 1979. Transaction-Cost Economics: The Governance of Contractual Relations. J. Law Econ. 22, 233–261.

Windrum, P., Birchenhall, C., 2005. Structural change in the presence of network externalities: a co-evolutionary model of technological successions. J. Evol. Econ. 15, 123–148.

Woo-Cumings, M., 1999. The developmental state. Cornell University Press.

World Bank, 2012. State and Trends of the Carbon Market.

World Energy Council, 2013. World Energy Perspective: Cost of Energy Technologies.

Yin, R.K., 2013. Case Study Research: Design and Methods: Design and Methods. SAGE Publications.

Yip, G.S., McKern, B., 2016. China's Next Strategic Advantage: From Imitation to Innovation, 1 edition. ed. MIT Press, Cambridge, , Massachusetts.

Zhou, L., 2013. Can China's Emergence as Carbon Market Boost the Certified Emissions Reduction Price? [WWW Document]. URL www.worldwatch.org/can-china%E2%80%99s-emergence-carbon-market-boost-certified-emissions-reduction-price-0