Intermediary organisations for knowledge exchange:

A comparative study of the agricultural biotechnology sector in the Netherlands and the UK

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A thesis submitted in April 2011 in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

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

Signature…………………………………………………..

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Summary

This dissertation, by comparing the agricultural biotechnology sector in the Netherlands and the UK, aims to understand the advantages and disadvantages posed by intermediary organisations for the promotion of knowledge exchange between universities and industry. An original conceptual framework has been constructed to allow a systematic analysis of intermediaries according to the functions they fulfil. The framework suggests that intermediaries can fulfil one or more of the following functions: access to human resources, access to the knowledge base, opportunities for commercialisation, access to facilities and other infrastructure, and access to networks. In order to move beyond the limitations brought about by differing nomenclature for intermediaries, the framework also proposes four ideal types of intermediaries derived from an analysis of existing intermediaries. The results of the empirical study reported here show that the roles of intermediaries are dependent on the characteristics of the sector as well as the history and configuration of existing national institutions. The policy implications of this study are several-fold. It is shown in this dissertation that application of certain dominant models of intermediaries can result in disadvantages for sectors like agricultural biotechnology that differ in important respects from the more frequently studied sectors, where these intermediaries seem to work better. This study of the agricultural biotechnology sector showed that there is space for new configurations of intermediaries such as sectoral technology transfer companies. The study highlighted that the crucial element for knowledge exchange is the production of knowledge itself. After identifying certain weaknesses in the UK agricultural sector and strengths within the Netherlands, the dissertation finds that large collaborative programs tend to facilitate knowledge exchange, while collaborative research and training can be a path for overcoming weaknesses in the system. By comparing the Netherlands and the UK, this study also showed that the presence of a strong industry is necessary for the uptake of knowledge originating from the research base.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AFRC	Agricultural and Food Research Council
AWT	Advisory Council for Science and Technology Policy (in Dutch: Adviesraad voor het Wetenschaps- en Technologiebeleid)
BBSRC	Biotechnology and Biological Sciences Research Council
BERD	Business Enterprise Expenditure on R&D
CBSG	Centre for BioSystems Genomics
DEFRA	Department for the Environment, Food and Rural Affairs
DLO	Agricultural Research Organisation- Netherlands
DTI	Department of Trade and Industry
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
HEFCE	Higher Education Funding Council for England
HEIF	Higher Education Innovation Fund
ILO	Industrial Liaison Office
IPR	Intellectual Property Rights
KNAW	Royal Netherlands Academy of Arts and Sciences (in Dutch: Koninklijke Nederlandse Akademie van Wetenschappen)
LNW	Ministry of Agriculture, Nature and Food Quality (in Dutch: Ministerie van Landbouw, Natuurbeheer en Voedselkwaliteit)
MNE	Multinational Enterprise
NGI	Netherlands Genomics Initiative
NPK	New Production of Knowledge
NSI	National Systems of Innovation
NWO	Netherlands Organisation for Scientific Research (in Dutch: Nederlandse Organisatie voor Wetenschappelijk Onderzoek)
OCW	Ministry of Education, Culture and Science (in Dutch: Ministerie van Onderwijs, Cultuur en Wetenschappen)
OECD	Organisation for Economic Cooperation and Development

PSRO	Public Sector Research Organisation
SMEs	Small and Medium Enterprises
STW	Dutch Technology Foundation
TH	Triple Helix
TNO	Netherlands Organisation for Applied Scientific Research (in Dutch: Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek)
TTI-GG	Technological Top Institute – Green Genomics
TTO	Technology Transfer Office

Acknowledgements

This dissertation would not have been possible without the help and guidance of several individuals who contributed in one way or another to the completion of this study.

First and foremost, I would like to thank my supervisors Ben Martin and Aldo Geuna. Ben has provided me with invaluable feedback in every aspect of my dissertation. I may finally use this medium to express that I liken him to my dad in his academic style: challenging, sometimes painfully honest but always fair, trustworthy and very generous with his time and feedback. I would like to thank Aldo for providing me again with challenging yet vital feedback over the years, which I believe have made me a better researcher. I would like to thank you both for your patience and regret that I couldn't show the best of myself.

I would like to thank PRIME Network of Excellence for supporting me with a mobility grant to conduct my fieldwork in the Netherlands. Also, I would like to thank Harro van Lente for his guidance and valuable feedback during my visit to the Department of Innovation and Environmental Studies in Utrect University.

I would like to thank my anonymous interviewees in the Netherlands and the UK, for their time and their answers, which provided me with valuable, original data.

Living in Brighton has been a wonderful experience thanks to a huge number of people and events that I couldn't list here. But there are a number of friends from Brighton and away who gave me indispensable emotional support from the beginning till the end of my PhD, which consists not only of the thesis itself but also the personal challenges associated with the process. For this reason I would like say a heartfelt thank you to: Betta, Bruno B., Daga, Dajana, Eugenia, Flo, Ilke, Josh, Jules, Kai, Kalinca, Katie, Maria, Ohid, Oli, Ozge, Popi, Rob, Roberto, Sara, Seda, Susana, Ubi, and Yari.

I would like to thank the research committee members through the years who have prompted me to sharpen my ideas. I would like to thank Janet, Danni and the members of the Keith Pavitt library for their administrative support and patience. Fellow colleagues in SPRU should be mentioned for making this department an intellectually stimulating and fun place to work in. When I decided that I want to do a PhD, I wanted to do it in SPRU and to this day I am proud of the choice I made.

Not to be forgotten are Pablo D'Este, Martin Meyer, Ismael Rafols, Pari Patel, Aldo Geuna and Nick von Tunzelmann for employing me in their projects, which have contributed to expanding my horizons within the field and helped to finance myself during the course of my studies.

Last, but certainly not the least, I would like to thank my parents. I cannot find the words to express how grateful and forever debted I am for your support in so many ways. No one else would sacrifice so much from their lives for the unconditional support you have shown me. I dedicate this dissertation to you.

CHAPTER 1: INTRODUCTION

In this dissertation, the aim is to understand the advantages and disadvantages offered by intermediary organisations in promoting knowledge exchange between university and industry. Intermediary organisations, as defined in the boundaries of this study, refer to those organisations that are located between university and industry and which have the aim of facilitating knowledge exchange between these two sectors. Some examples of such organisations are technology transfer offices, science parks, consultancies and research organisations. The rest of this chapter will explain the motivations behind this study, why it is an important subject to explore and how this dissertation aims to contribute to this area of research.

The main motivation behind this dissertation is a policy problem arising from a discrepancy between the policy tools concerning intermediary organisations and the academic literature studying these organisations. The notion of a so-called "European Paradox", which emerged 15 years ago, refers to a "major weakness" of Europe in "transforming the results of technological research and skills into innovation and competitive changes" (EC 1995: 5). The Green Paper that introduced the European Paradox concept suggests a variety of actions to facilitate innovation and does not focus solely on the interface between university and industry. Nevertheless, subsequent references to the so-called European Paradox have perhaps disproportionally focused on the 'translation problem'. Governments in many countries have focused on mechanisms facilitating university-industry links with the aim of overcoming this 'translation problem,' and intermediary organisations in general represent one of the mechanisms that may facilitate such links.

The existence of intermediary organisations is not a new phenomenon but what is new is the emergence of distinct types of intermediary organisations. It can be argued that a close link can be observed between the dominant types of intermediary organisations and the underlying expectations about the role of university with regards to the economy and society in general. In the following paragraphs I will set out the background to this study, surveying the development of the literature with the aim of specifying where this dissertation is positioned.

Following Vannavar Bush's "The Endless Frontier" (1945), science and scientific institutions enjoyed relatively generous government funding and considerable autonomy for several decades. However, this only lasted until the 1970s, when governments had to tighten their budgets and public spending in the light of global economic crises. Academic and policy debates in the 1970s focused on 'science policy', which was essentially concerned with the contribution of scientific research, carried out mainly in universities and public-sector research organisations, to society. The main focus was on the supply-side of the research system, with studies focusing on cross-country comparisons to determine the key elements of successful research systems (e.g. Ben-David 1968; OECD 1981; Pavitt and Walker 1976). Public sector research organisations were the dominant form of intermediaries where translational or mission-oriented research took place.

In the 1980s, the focus of academic studies and policies in industrialised countries started to shift from strengthening the supply-side to benefiting from an already strong science base. These studies looked at the processes of 'commercialisation' of academic research and certain organisations that might facilitate this process, such as industrial liaison offices (e.g. Rothwell 1982; OECD 1984). Academic studies also started to analyse the various channels of university-industry relations and the factors that affect them (Rothwell 1985). In the meanwhile, the emergence of the modern field of biotechnology and the close links between university and industry prompted several studies looking at these links (e.g. Kenney 1986; Shohet & Prevezer 1996).

Beginning in the late 1980s, studies on university-industry links started to diversify and to look into distinct forms of intermediary organisations such as science parks (i.e. Monck et al 1988; van Dierdonck et al 1991; Massey and Wield 1992; Westhead & Storey 1995), technology transfer offices (i.e. Guston 1999; Bercovitz 2001; Siegel et al 2003), consultancies (Bessant & Rush 1995) and others. These earlier studies on science parks and technology transfer offices have shown that the benefits provided by such organisations for the knowledge exchange process tend to be rather limited.

While the academic literature did not present strong evidence regarding the benefits of such organisations, government policies in some countries, like the UK, continued to place universities in the spotlight and funded dedicated programmes for technology transfer from universities, while reducing the share of block grants for universities and research institutes. Motivated by this disagreement between policy and academic literature, this dissertation aims to contribute to the academic literature by carrying out a systemic study of intermediary organisations: this involves developing an original conceptual framework, as well as making relevant policy recommendations, which are discussed in chapter 9.

Previous literature on intermediary organisations remains rather fragmented. As noted in the previous paragraphs there are numerous studies that have analysed individual types of intermediary organisations such as technology transfer offices, science parks, public research organizations and so on. However, studies in the academic literature that systematically analyse intermediary organisations are limited (van Dierdonck et al 1990; Hassink 1997; Howells 2006). Within the innovation systems field, much attention has been given to firms, and to universities to a certain extent, but intermediary organisations have been somewhat neglected in comparison. Based on a review of university-industry interaction channels, this dissertation suggests five functions and a classification scheme for intermediary organisations through which a systemic analysis of intermediary organisations can be conducted. By doing so, this dissertation contributes to a section of innovation systems where less is known.

In order to study the advantages and disadvantages of intermediary organisations, I chose to make a comparison of the agricultural biotechnology sector in the Netherlands and the UK, a choice that has a number of important implications. By comparing the Netherlands and the UK, this dissertation sets out to understand the differentiating role of national institutions and policies with regards to the role of intermediary organisations. Studying two countries with similar socio-economic conditions, but different sets of intermediary organisations further illustrates the importance of national systems, demonstrating how national institutions and history contribute to emergence and configuration of such organisations.

Regarding the choice of the sector, many of the previous studies on university-industry relations and intermediary organisations have focused on 'high-tech' sectors such as medical biotechnology and nanotechnology. As mentioned previously, the emergence of fields like biotechnology and nanotechnology have prompted studies that analysed frequently occurring university-industry relations in these fields. Nevertheless, as will be discussed in the empirical chapters, policies based on the observation of a few select sectors may have negative consequences for other sectors. The agricultural biotechnology sector benefits from high-tech applications as well, but does not fit the model of the more 'popular' high-tech sectors such as medical biotechnology. As such, studies looking at university-industry relations and intermediary organisations in this sector are limited and focused mainly on the US (Huttner et al. 1995; Foltz et al. 2000; Alston et al. 2006 among others). Studying intermediary organisations in a less studied sector like agricultural biotechnology not only makes possible a more novel empirical contribution but also helps to demonstrate how certain sector-specific characteristics may affect the role of intermediary organisations, in addition to national characteristics. Furthermore, although it has been studied much less, agriculture is a field that affects a lot of people not only in the Netherlands and the UK but also around the world.

In the rest of this section, I will set out a conceptual roadmap of how I try to study the research problem at the centre of this dissertation, building on the background presented in the above paragraphs. To remind the reader again, the main research problem of this dissertation is;

To identify, analyse and explain the advantages and disadvantages of intermediary organisations in promoting knowledge exchange between university and industry.

Two further sub-research problems can be formulated in order to address the main research problem more effectively:

- To what extent do national institutions affect the role that intermediary organisations play?

- To what extent do specific sectoral characteristics affect the role that intermediary organisations play?

As explained above, this dissertation argues that much of the academic literature on intermediary organisations remains fragmented and biased towards high-tech sectors. It is further suggested that government policies consciously or unconsciously draw upon a rather small segment of successful high-tech fields in dedicating funds for knowledge-transfer activities. In addition, it is argued that some of the dominant policy tools for promoting university-industry relations are based on an implicit assumption of a linear model of innovation and technology transfer and are biased towards commercialisation activities, running the risk of neglecting or underutilising a broader set of mechanisms for promoting these relations.

It is argued here that in order to understand what kind of intermediary organisations would best promote knowledge exchange, it is necessary to establish a few essential fundamentals. The first argument is that the roles that organisations play are dependent upon the components of the innovation system they are embedded in. Intermediary organisations cannot be assessed without understanding the structure of universities, industry, and the broader institutional context they are embedded in. By drawing upon the innovation systems literature, I argue that national and sectoral characteristics will affect the roles that intermediary organisations may or may not play.

The second argument is that, in order to promote relations between university and industry, a 'knowledge exchange' view should be adopted, instead of a 'technology transfer' one. A study of the academic literature on university-industry relations shows that the relations between the two sectors takes place through a broad range of channels, and in most cases direct commercialisation activities are among the least important of these channels. For an intermediary organisation to facilitate university-industry knowledge exchange, it should be facilitating several of these channels.

As part of the above argument, this dissertation proposes an original conceptual framework for systematically analysing these interactions channels in which intermediary organisations can play a role. By reviewing the literature on university-industry relations, channels of interactions are classified into five main functions, which allows for a simple but systemic study of intermediary organisations rather than an ad-hoc process of trying to define where they can serve.

The second part of the framework aims to extend this systemic analysis by classifying intermediary organisations into more abstract categories according to the roles they can play rather than using specific nomenclature such as ‘technology transfer offices’ or ‘science parks’. These abstract categories draw upon both generic and specific intermediary organisational studies, but categorise them according to the roles they play in the knowledge-exchange process. The two parts of the framework help to address the research question in a systemic manner by analysing what type of intermediaries provides advantages (or disadvantages) for each particular function.

The conceptual framework has provided the basis for the fifty-six interviews conducted with different stakeholders from industry, university and intermediary organisations. Original primary data collected through these interviews were used in combination with secondary data for the analysis conducted in the empirical chapters. The results of the analysis confirmed the importance of national institutions and sectoral characteristics but also indicated that some of the dominant policy tools for facilitating university-industry relations are more problematic for the agricultural biotechnology sector.

The results presented in the empirical and conclusion chapters are likely to be important for policies regarding the facilitation of university-industry relations for several reasons. Firstly, by showing once more the differentiating effects of national institutions on the role of intermediary organisations, this study draws attention to the parts of the innovation system that should be considered along with policies regarding the university-industry interface. Secondly, by studying a less traditional ‘high-tech’ sector, we suggest alternative mechanisms and intermediary types for promoting knowledge exchange between the two sectors.

1.1 Overview of the dissertation

Chapter 2 firstly looks at the academic literature on systems of innovation, and discusses its rationale. It then explains why the national systems of innovation approach offers a more suitable framework for studying the research problem of this dissertation. The focus is then narrowed down to a particular part of the system: university and industry and more specifically the links between them. As well as reviewing the motivations, channels and barriers concerning these links, I discuss two major fields of academic literature that explicitly study the changing role of universities. Finally, I argue that the term 'technology transfer' cannot capture the breadth of university-industry interactions and that there is a need to shift to a 'knowledge exchange' perspective.

Chapter 3 develops the conceptual framework of this dissertation through a number of steps. Firstly, the theoretical and more generic literature on intermediary organisations is discussed in relation to five derived roles. This is followed by an analysis of the literature on current intermediary organisations across these roles, leading to a classification of intermediaries into four main types. Finally, in order to determine what roles they *should* play for facilitating knowledge exchange, the existing channels of university-industry relations are categorised in terms of the five functions.

Chapter 4 spells out the research methods that have been used in this dissertation, explaining the choice of qualitative approaches used, justifying the choice of the sector and the countries studied as well as the steps taken in analysing the data.

Chapter 5 presents the results of the empirical work conducted under the five functions making up the conceptual framework. It discusses each function in terms of whether there is a role for intermediary organisations for the particular function, and also discusses other issues arising from the interviews. Based on the fieldwork, I suggest a fifth type of intermediary organisation type as well as drawing attention to the role of intermediary *institutions*.

Chapter 6 analyses the agricultural biotechnology sector through the lens of technological regimes to show how sectoral characteristics affect the way that intermediary organisations function. It also makes a brief comparison of the sector in the USA and Europe to show how a different configuration of the technological regime for the same sector may affect the role of intermediary organisations.

Complementing the previous two chapters, Chapter 7 discusses the institutional characteristics of the two countries that have been studied. This includes a discussion of the paths taken by science, technology and innovation policies in the

Netherlands and the UK over time as well as the evolution of the broader research system. The chapter also draws attention to the solutions that have emerged in the national innovation systems related to the weaknesses in the agricultural biotechnology sector. A comparison of the national institutions of the two countries concludes the chapter.

Chapter 8 brings together the previous three empirical chapters and discusses each of the five functions across the five intermediary organisations and intermediary institutions. Furthermore, it discusses the results of this dissertation in comparison to the existing academic literature on intermediary organisations.

Chapter 9 provides a summary of the main theoretical and empirical contributions made by this dissertation to the body of knowledge as well as discussing the implications of the findings for policy. The limitations of the study, future areas of improvement and further research are also addressed in this chapter.

CHAPTER 2: SYSTEMS AND UNIVERSITIES: A SELECTED REVIEW OF THE RELEVANT LITERATURE

While intermediary organisations make up the focal theme of this dissertation, it is not possible to analyse their roles without understanding the system they are embedded in. As has been noted in the introduction chapter, intermediary organisations are defined in this dissertation as those located between university and industry and having the aim of promoting knowledge exchange across these sectors. The emergence of intermediary organisations is closely related to the change in the dynamics of systems of innovation and the 'new' or 'enhanced' role of university within the system.

In this chapter, I will focus on the analysis of two main bodies of literature related to the above argument: systems of innovation and universities. Their relation to the main theme of this dissertation is two-fold: analytical and theoretical. The systems of innovation framework is the main analytical framework used for the empirical chapters and therefore it is necessary to understand its building blocks. Similarly, the conceptual framework presented in the following chapter is built upon the various channels of university-industry interaction. Theoretically, the two bodies of literature relate to the critical stand taken in this dissertation against the reduction of 'knowledge exchange' to 'technology transfer'. The systems of innovation literature is also closely associated with the idea of 'systems failure', an alternative view to the 'market failure' idea, which is the dominant argument within many policy circles. Understanding the differences between these two underlying views is important as they have different implications for policy-making in many areas including those regarding universities and intermediary organisations. Similarly, discussing the nature of university-industry relations and the 'new' role of universities, will support the arguments put forward in the empirical chapters regarding the need for a broader approach to knowledge exchange, including the role played by intermediary organisations.

The chapter starts from the broader systems of innovation literature and gradually focuses down to one of key components of the system, universities and their relationship with industry. Section 2.1 explains the emergence of the systems of innovation concept and justifies the choice of 'national systems of innovation' for this dissertation, as the main framework used for studying the research question. Section 2.2 will look at the role of university and how it has changed - or not - over time as well as looking at university-industry relations. Finally, building on the first two sections, section 2.3 will aim to make a theoretical case for replacing the 'technology transfer' concept with a broader 'knowledge exchange' one, which is then empirically supported in the final chapters.

2.1 Systems of innovation

The systems of innovation (SI) framework has been central to the field of science, technology and innovation studies over the last two decades. I will selectively review parts of this literature, covering the definitions and scope of systems as defined by scholars in the field, as well as its emergence and connection to policy. Finally, I will discuss the choice of national systems of innovation over the other branches of SI as the main analytical tool for this dissertation. This section will start with a discussion of the differences between the 'market failure' and 'systems failure' concepts, setting the scene for examining the evolution of SI literature.

2.1.1 From a market failure to systems failure understanding

Systems of innovation (SI) has become a well-known framework not only among the academics but also policy practitioners since its emergence in the late 1980s. Academic journals and policy documents frequently refer to systems and the main concepts associated with this framework, including those like the importance of interaction and learning. Nevertheless, recommendations and policy tools are often still based on older notions of innovation such as the linear model and market failure. In this section, I will explain what the market failure rationale means, how it is connected to neoclassical economics, and why the systems failure emerged as an alternative rationale through the emergence of evolutionary economics and systems of innovation framework.

The concept of market failure is rooted in the neoclassical framework of economics[1]. Differing from classical economics where technology has been considered as a residual, neoclassical economics included technology as a third

[1] For a more detailed discussion of the place of technology within the neoclassical production theory, please refer to Smith (1994).

factor in the production function of Solow, along with capital and labour. Solow referred to 'technical change' as "a short-hand expression for *any kind of shift* in the production function" (1957: 312) that cannot be explained by changes in the capital or labour. In this sense, it did not really explain what might have caused these shifts. The new growth - or endogenous growth - theory goes a step further than the neoclassical framework to acknowledge the positive externalities by factors such as human capital, science and technology yet still does not provide a detailed explanation of how they affect production (Romer 1994). While new-growth theory looks at the *effects* of innovations and knowledge (Edquist 2001: 2), scholars of evolutionary economics took a step further to look at the *determinants* of innovation and knowledge, and they consider technology as the main driver behind structural change and economic development (e.g. Metcalfe 1995)[2]. The importance given to the role of technology for innovation raises questions about some of the assumptions underpinning the market failure idea, especially in relation to the characteristics of information and knowledge discussed in the following paragraph.

The neoclassical assumption about the nature of science and technology, or knowledge in general, led to the formation of the market failure rationale for science and technology policies. Two seminal papers by Nelson (1959) and Arrow (1962) have been immensely influential within the economics of science literature to date[3]. Together they argue that the non-excludability and non-rival characteristics of science prevent the creators of knowledge from fully appropriating the returns to their investment. Coupled with their implication that knowledge is easily duplicable, "market forces are inadequate to deliver the socially optimal level of scientific research", leading to a market failure (Geuna 2001: 608). The resulting underinvestment in research by private parties then creates a justification for government intervention. Smith (1994) argues that the market failure approach results in simple policy solutions; the problems of risk

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[2] It should be noted that although technology's role in innovation has been brought to the spotlight by evolutionary economists in recent last decades, eminent scholars of evolutionary economics point out that prior to the neoclassical economics, economists from the 19th century including Adam Smith, Karl Marx and Joseph Schumpeter have given an important role to technology as well (Dosi and Nelson 2009).

[3] A quick search in Google Scholar reveals around 6500 citations for the two papers combined (accessed May 2010).

and indivisibility associated with knowledge are addressed by either the direct production of knowledge by the public sector or through provision of subsidies for private entities such as tax breaks, and subsidies or intellectual property rights address the problems of appropriability. While tax breaks and tools associated with intellectual property are widely used today, they present several shortcomings since the underlying market failure rationale has severe shortcomings itself.

Several problems associated with the market failure approach have been discussed in the academic literature[4], but in this section I will particularly focus on the weakness of this approach in terms of the way 'knowledge' is treated as 'information'. Hauknes and Nordgren write that the market failure rationale is associated with the microeconomic theory of firm where knowledge is considered to be generic, codified and immediately accessible, and therefore it does not account for differences between capabilities, knowledge and information (1999: 2). On the other hand, scholars of evolutionary economics have long shown that knowledge is not easily accessed, transferred or codified. It has been long argued by scholars in the innovation literature that technology differs from information. David and Foray argue that information "takes the shape of structured and formatted data that remains passive and inert until used by those with the knowledge needed to interpret and process them" and that knowledge is " a matter of cognitive capability" (David and Foray 2003: 4). The authors further discuss the implications of this distinction in relation to the reproduction of knowledge and information, arguing that reproduction of knowledge is not costless and that some parts of it remain tacit (ibid). Such characteristics of knowledge challenge the underlying assumptions of the market failure rationale about the non-excludability and non-rivalry characteristics of science mentioned before. Firms, as well as individuals, need to have certain capabilities to use knowledge for innovation and as Dosi writes, technology is cumulative and firm-specific and therefore its development is also constrained by the existing activities of firms (Dosi 1988: 1131). Building on these arguments, one can see the shortcomings of an IP-related policy for underinvestment. IP protection is limited to codified knowledge or

[4] See Dosi et al 2006: 1111-1112.

information and cannot cover the tacit elements of knowledge.

Scholars from the systems of innovation literature put forward the ‘system failure’ rationale as an alternative to the ‘market failure’ one, where the complex nature of knowledge is taken into account within the processes of innovation. The system failure rationale places the emphasis on questioning whether the appropriate institutions are in place and if the connection between the actors of the system is satisfactory. Edquist presents four broad categories of such failures where functions, organisations, institutions or the links between these elements in the SI may be inappropriate or missing (Edquist 2001: 19). Based on these missing elements or links, the government’s role in policy changes from funding tax breaks or drafting IP regulations to addressing these elements, links and interactions.

The differences between the market and system failure rationales have important implications for the justification of public funding of knowledge. Within the market failure rationale, governments fund R&D assuming that investment by private firms will be sub-optimal. Pavitt writes that the original information-based rationale for public funding of research has neglected two important elements; the “heavy infrastructure…required for the assimilation of the results of the research performed elsewhere” (referring to the assumption of easy duplicability) and also the trained human resources who have problem solving capabilities (Pavitt 2001: 766). These elements show that policies should go a step further beyond the generation and transfer of knowledge and include the system surrounding them. Within the systems failure rationale and systems of innovation framework, the justification for government funding of R&D is much broader where the focus changes from market failure to improving competitive performance and structural change (Salter & Martin 2001: 511). As Martin argues, the new rationale for public intervention focuses on overcoming system failures and developing and strengthening links in the systems of innovation (Martin 2007: 16). This involves concentrating not only on the performance of individual organisations within the system but also on how they interact as parts of a collective (Smith 1994: 3). In the next section, I will briefly review the constituents of a system of innovation.

Table 2.1 Summary of the differences between the market failure rationale and the systems failure rationale

	KNOWLEDGE	SOLUTIONS	PUBLIC FUNDING RATIONALE
MARKET FAILURE	Neoclassical assumptions: generic, codified, easily accessible and transferable	Tax breaks and subsidies IP laws Public funding of R&D	Justified due to suboptimal investment by private firms
SYSTEMS FAILURE	Tacit components, hard to codify and transfer		

Source: author's own summary

2.1.2 What makes up a system of innovation?

The first use of "systems of innovation" (SI) concept coincides with the end of 1980s and beginning of 1990s. Lundvall (1992) indicates that Freeman may have been the first one to use the 'national systems of innovation' concept in his 1987 book, although recently Freeman has suggested that he might have picked up the concept from Lundvall (2008). Regardless of the first use of the concept, both authors agree that the concept can be traced back to the idea of Friedrich List's "The National System of Political Economy" published in the mid-1880s (Freeman 1995). In this section I define what makes up a system of innovation, drawing mainly upon on the national systems of innovation literature. Nevertheless, these fundamental definitions regarding the components of systems are shared across the regional and sectoral systems of innovation literature as well.

The book on National Systems of Innovation (NSI) edited by Lundvall (1992) focuses on the theoretical aspects of NSI, bringing 'learning' to the forefront as the most important part of NSI and placing an emphasis on user-producer relationships. In a more recent paper Lundvall argues that since the emergence of the NSI concept there has a been a distortion whereby the focus has shifted from experience-based learning and tacit knowledge - DUI (doing, using, interacting) learning - to more science-based innovation and formal technological infrastructure - STI (science, technology, innovation) learning - (Lundvall 2007: 3-

4). In this dissertation the focus is indeed on the STI learning, although the importance of tacit knowledge is acknowledged particularly because STI learning is often reduced to codified knowledge.

Within Lundvall's book the main unit of focus within the system is the firm, although the roles of a variety of institutions and support organisations are discussed as well. The 1993 book edited by Nelson has a similar approach to innovation with a number of empirical studies where the firm is still at the centre of innovation, although the role of institutions is emphasised more than in previous works.

Comparing the two above-mentioned works, Marsili (1999) writes that Lundvall looks at the organisational and institutional changes as well, while Nelson looks mainly at technical changes. She further adds that, while Lundvall focuses on informal institutional set-ups, Nelson focuses on formal organisations and institutions. Before discussing the differences between organisations and institutions, it is useful to take a step back and remind ourselves of what is a system and what are its components. Carlsson et al. (2002) define a system as " a set of interrelated components working towards a common objective" - i.e. systems are made up of components, relationships, and attributes. Lundvall writes that a system of innovation "is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge" (Lundvall 1992: 2). Connecting this description with the definition of Carlsson, the common objective in a system of innovation is the production and diffusion of new knowledge. In this dissertation, I would like to extend the common objective from "new, and economically useful knowledge" to include socially relevant knowledge as well. As will be discussed further in the later sections and chapters, 'economically' useful knowledge can sometimes be misleading, especially when considering the role of universities.

Components, as described by Carlsson et al. (2002), are the active bodies within the system; they can be material or non-material, physical or non-physical, and can range from firms to traditions. Relationships constitute the linkages between these components, which cause interdependencies between the various components. If chemistry were used as an analogy, the components and relationships would resemble atoms and the bonds between atoms respectively. A change in relationships causes a change in the system. Regardless of the emphasis, the common denominator is that the performance of the economy depends not only on the performance of individual components of the system but also on how they link and interact (Johnson and Gregersen, 1995). The interactions are often effected by the institutions, which are defined in the next paragraph.

It should also be mentioned that authors within the SI literature have differentiated between institutions and organisations within a system of innovation. Edquist defines institutions as "sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups", and he considers patent laws and norms influencing the relationship between universities and firms as important examples of institutions (Edquist 1997: 5-6). The author defines organisations as "formal structures with an explicit purpose" (p.6) and gives as examples firms, universities, venture capital organisations and the like. Other authors have different definitions and scopes for what counts as an institution or organisation. Nelson and Rosenberg (1993) include firms, industrial research labs, universities and government labs within the scope of institutions alongside 'softer' ones such as technology policies.

As will be seen in the discussion in Chapter 5, the differentiation between organisations and institutions is kept in this dissertation as well. As defined by Edquist, organisations in this study will refer to more formal and 'hard' structures, such as firms, universities, science parks, technology-transfer offices and so on. Similarly institutions will cover the broad range of 'softer' elements described above as well as some formal structures that have been formed for a limited amount of time, such as government programs.

Although the topic of functions will be discussed in the next chapter in relation to the conceptual framework, it is worthwhile mentioning that some scholars have discussed functions of innovation systems. Johnson (1992) attributes some functions to institutions, such as reducing uncertainty, coordinating the use of knowledge, mediating conflicts and providing incentive systems. Furthermore, he argues that institutions shape the innovations, while countries differ in their institutional set-ups. The empirical chapters will indeed support this point by showing how different national and sectoral institutions affect the relations between university and industry.

Lundvall and Johnson (1994) discuss in great length how pure market economies are not sufficient to effectively organise what they consider to be the most fundamental resource of current economies, knowledge, and the most important process, learning. Considering that the innovation process consists of different types of knowledge, each with 'transactional peculiarities' (p.30), they argue that pure markets do not constitute a proper institutional set-up and there is a role for government in supporting learning processes. It is for this reason that different countries will have varying institutional set-ups (Lundvall and Johnson: 1994). Furthermore as Johnson and Gregersen (1995) write, institutional set-ups are connected to the nation-state and the specific production structures that national economies have (p.7). The next section will discuss further why the nation-specific elements are important and why the NSI is the main framework to be used in this dissertation.

2.1.3 Why 'national' systems of innovation?

While the national systems of innovation framework was the first branch of systems of innovation to emerge, it was soon followed by regional systems of innovation, technological systems and sectoral systems of innovation. In this section I discuss why national systems of innovation is chosen as the main analytical framework for answering the research question of this dissertation. Chapter 7 will further justify this choice by empirically showing how different institutions in the Netherlands and the UK have affected university-industry relations within the agricultural biotechnology sector. While national systems of innovation is the foremost framework for this dissertation, concepts from sectoral systems of innovation will be employed as well to show that even within the same national system, there are important differences between sectors, which should be taken into account. I will also introduce the concept of technological regimes, which chapter 7 will draw upon to discuss the characteristics of the agricultural biotechnology sector. Making use of both frameworks will also show that industries are affected by both national and sectoral characteristics and therefore further support the argument that 'one size fits all' policies are not suitable across countries or sectors.

De le Mothe and Niosi have pointed out that national systems of innovation is a suitable choice framework if "one's main concern is the impact of institutional structures and the role of national policy" (De la Mothe & Niosi, 2000: 10). Given that this dissertation is a comparative study of two countries and it aims to show the effects of different national institutional set-ups on the industry, the description of the authors sums up nicely the suitability of national systems of innovation as the main analytical framework to be used as a guidepost for the purposes of dissertation. Chapter 7 supports this point through an analysis of the national systems in the Netherlands and the UK. It was mentioned in earlier sections that within a system of innovation, the interaction between the components of a system is as important as their individual performance. Both countries have similar components in terms of organisations and institutions: firms, universities, patent laws, and the like. However, there are important differences between the countries in terms of how these individual institutions are governed as well as the interactions between them. For example, as Chapter 7 will show, the patent laws regarding agricultural biotechnology in the USA have a broader scope than the ones in European countries, and this has major effects on shaping the nature of university-industry interactions and in the particular the commercialisation process. Another example, which is explained in detail in Chapter 7, is regarding the commercialisation processes and policies as well; while in the Netherlands tools for commercialisation are more embedded within sectoral policies, in the UK they are more centralised and generic.

As the field has evolved, scholars within the broader innovation systems literature have pointed to various weaknesses of the *national* systems of innovation framework and also put forward alternative regional, sectoral and technological systems approaches. De la Mothe and Niosi argue that innovation systems differ greatly across industries and they are increasingly international (2000: 9). The authors' first point is particularly important and this is why certain aspects of sectoral systems of innovation (SSI) are used within this dissertation as well. However, choosing the SSI or Technological Systems frameworks as the main analytical tools would have certain shortcomings. The following paragraphs will briefly describe these alternative approaches and the shortcomings of these approaches for answering the research question of this dissertation.

Sectoral Systems of Innovation

As defined by Breschi and Malerba (1997), a Sectoral System of Innovation (SSI) is "that system (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies" (p.131). Three main factors are considered to affect a sector: knowledge and technologies; actors and networks; and institutions. Actors and networks are connected by market and non-market relationships, which differ across sectors.

Although the focus is on sectors, SSI also takes into account national institutions in terms of their effects on different sectors. A possible weakness of using SSI as the main analytical framework in this dissertation is the danger of missing out national institutions which might not be directly related to the sector but still have an indirect effect on the sector under consideration. Nevertheless Chapter 6 will use the concept of technological regimes to analyse the characteristics of the agricultural biotechnology sector and how these affect the role of intermediaries in the sector. The next section will discuss the technological regimes and the associated concepts, which will be applied to the case of agricultural biotechnology sector in chapter 6.

Technological regimes

The concept of technological regimes has long been used to explain the differences between industries (e.g. Audretsch and Acs 1990; Audretsch 1997; Van Dijk 2000; Castellaci 2007).

Most of the empirical works on explaining the industrial differences through technological regimes are econometric studies on large manufacturing datasets. While these studies are extremely helpful in understanding the concepts underlying technological regimes, they do not take into account the role of national institutions. The article by Castellaci (2007) is an exception to this, acknowledging that country specificities may affect the growth in industrial sectors through policies, specialisation patterns and macroeconomic performance as well as social, institutional and cultural factors affecting the interactions among economic agents.

Malerba and Orsenigo (1997) argue that evidence suggesting patterns of innovative activities showing differences across sectors but similarities across countries indicate that technological regimes are relevant in determining sectoral differences as long as the opportunity, appropriability and cumulativeness conditions are similar across countries. Van Dijk defines a technological regime as "a particular combination of opportunity, appropriability, cumulativeness conditions and the properties of the knowledge base, common to specific activities of innovation and production and shared by the population of firms undertaking those activities" (Van Dijk, 2000: 174). What these concepts mean is explained in the following paragraphs, which are then discussed for the case of agricultural biotechnology in section 6.1.

Cohen and Levinthal (1990) write that technological opportunity "represents how costly it is for the firm to achieve some normalised unit of technical advance in a given industry" (p.139). The authors further elaborate to say that there are two dimensions to it: "quantity of extraindustry technological knowledge" and "the degree to which a new unit of knowledge improves the technical performance of the firm's manufacturing process and products" (ibid). Dosi and Nelson define technological opportunities as the sources of knowledge upon which technological paradigms draw (2009: 18). Referring to technological paradigms, the authors write that opportunities may arise from knowledge gained through operating experience, or also, as in the case of 'high-tech' fields, through scientific research (Dosi and Nelson, 2009: 19). Castellaci (2007) writes that, based on the innovation literature, three different types of actors can be identified as external sources of opportunities: users, the science system and suppliers. The interest of this dissertation is on the interfaces between the science system and industry.

Appropriability conditions as defined by Dosi and Nelson (2009) refer to "the mechanisms through which such [technological] opportunities are seized, and the possibilities they entail for innovators to extract economic benefit from their technological advances" (p.18). An important argument that the authors highlight is that differences in the rate of technological progress are more related to technological opportunities than to stronger appropriability conditions (p.25). As evidence supporting the argument, they refer to the studies that show that stronger patents do not necessarily bring a significant increase in technological progress, and it may even be the case that stronger appropriability conditions hinder technological progress due to issues related to cumulativeness (ibid). In chapter 6 we will discuss how different appropriability conditions may actually account for differences between the innovative activities within the same sector but across different countries.

The concept of technological regimes has been used for industrial classifications as well. Dosi and Nelson (2009) refer to technological regimes as "distinct ensembles of technological paradigms with their specific learning modes and equally specific sources of technological knowledge" (p.31). The authors refer to the taxonomy of Pavitt (1984) and Schumpeter 'Mark I' and 'Mark II' as examples of work trying to capture some of these relations. The idea of technological regimes is related to the sectoral systems of innovation by the institutions governing research and training and the interactions between producers (Dosi and Nelson 2009: 32).

Marsili (2001) extends the Pavitt taxonomy from four to five categories, which are: the science-based regime; the fundamental-process regime; the complex (knowledge) system regime; the product-engineering regime; and finally the continuous-process regime. Of these, the science-based regime is the most relevant category to this dissertation. The science-based regime is characterised by innovative activities with a knowledge base in life and physical sciences, and it has high levels of technological opportunities, and high entry barriers due to the specificity of knowledge applications and high cumulativeness. The pharmaceutical industry is considered to be an example of a science-based regime.

Brink and McKelvey (2006) address the variation in technological regimes within the sub-sectors of biotechnology, although their selection of cases is not based on industrial divisions such as pharmaceutical, agricultural or industrial biotechnology, but on the basis of a matrix consisting of their knowledge base and incremental/radical knowledge development. Eventually the four quadrants in the matrix are exemplified by pharma, diagnostic, test and bioprocess firms, which were nevertheless related to the broader pharmaceutical industry and not agriculture. While a direct extraction from the results of the authors' study cannot be made for use in this dissertation and they approach the subject from a different angle, their policy implications suggest that 'bioscience' cannot be treated as a single industry (Brink and McKelvey 2006: 29).

Technological Systems

De la Mothe and Niosi write that the technological systems (TS) approach emphasises the importance of technological evolution and focuses on the concepts of networks of knowledge and competence (2000: 4). While one could argue that a biotechnology-based sectoral analysis can be carried out best through the lens of technological systems, there are major drawbacks associated with it considering the research question of this dissertation. Firstly, as Senker et al. (1999) point out, TS is limited to microeconomic considerations and does not give a central place to institutions. It will be shown in Chapter 7 that institutional configurations do affect agricultural biotechnology and how the intermediaries are structured. Secondly, the focus in TS is on the application of knowledge rather than its generation or diffusion. On the other hand, in this dissertation the focus is on the diffusion of knowledge and the role of intermediaries in this process. It will also be shown in Chapters 6 and 7 that the generation of knowledge is closely related with its diffusion.

Hekkert et al. (2007) argue that 'technology specific innovation systems' (TSIS) are better for studying and understanding technological change compared to national systems of innovation due to some shortcomings of the latter. NSI, they claim, is static with a focus on the social structure and comparison of performance, and therefore it does not place much emphasis on the dynamics of innovation systems (p.414). The other criticism they make is that the explanatory power of the framework lies at the institutional level rather than the individual level, which they consider to be quite powerful. While these criticisms may be true for the analysis of cases on emerging technologies, the field that the authors of TSIS look at, it can be argued that, for cross-country comparisons and more established sectors or technologies, institutions still play a much larger role than individuals.

Before moving further in the dissertation, it might be useful to first make some clarifications regarding the distinctions between technology, industry and sector. It will be shown in Chapter 6 that agricultural biotechnology as a whole is a new technology that has affected companies working in agrochemicals and plant breeding as well as certain others.

A sector is defined as “a distinct part or branch of a nation’s economy or society or of a sphere of activity”[5] whereas industries are sub-divisions of sectors. In this dissertation I look at three groups of companies conducting research: companies working in agrochemicals, companies working in certain fields of plant breeding and dedicated biotechnology companies in plant and crop science related areas. Within the standard industry sector (SIC) codes, plant breeding industries are located within the ‘agriculture, forestry, and fishing’ sector whereas agrochemicals is located under the ‘manufacturing’ sector. As will be discussed in greater length in chapter 6, agrochemicals and plant breeding companies have been brought closer by the emergence of agricultural biotechnology. It is therefore difficult to make a clear choice between sectoral innovation systems and technological systems, but, given the limitations mentioned in the above paragraphs and given the importance of sectoral differences, I have decided to use sectoral innovation systems as my secondary framework of analysis.

2.2 A system component: universities

As has been mentioned in the first part of this chapter, one of the basic notions of the systems of innovation literature is that firms do not innovate in isolation and interactions between the components of the system are just as important as the individual performance of the various components. In this section, the focus will be on an important component of any innovation system; universities, and their interaction with industry. I will briefly review the literature on university-industry interactions, looking at the reasons behind such interactions as well as factors affecting and barriers inhibiting them. Building on this, the role of universities will be discussed in section 2.2.2.

2.2.1 University-industry interactions

The literature on university-industry relations is very diverse, showing that there exist a variety of interaction channels: consultancy, contract research, joint research, human mobility and so on. In this section I will try to review what these

[5] http://oxforddictionaries.com

channels are, what are some of the factors that affect these channels, what are the reasons that universities and industry engage in relations with one another, and what are the barriers to these interactions. It is important to review these in order to be able to critically analyse the discussions around the role of universities and the suggested policy mechanisms that relate to these roles.

Channels and factors

The number of studies that have looked at the different channels of university-industry interactions is many. A compilation of these channels based on the literature is given in table 2.1. I will refer to the literature on several of these channels with the aim of comparing the results of this dissertation, in terms of university-industry relations in agricultural biotechnology, with the existing literature.

Table 2.2 University-industry links

Assistance from industry with activities
Use of university staff, staff exchange, internships and studentships
Sharing of facilities
Role of “third party” organisations
Financial support from industry for university
Collaborative/ joint research
Consultancy
Training, courses
Publications
Conferences, networks
Informal contacts
Spin-offs, start-ups
Patents, licenses, other IPR forms
Science/ technology parks, innovation centres
Incubators

Sources: Synthesised by the author from various sources (OECD 1981; Nauwelaers and Wintjes 2001; Schartinger et al. 2002; Debackere and Veugelers 2005; Brennenraedts et al. 2006; D’Este and Patel 2007).

Of the channels listed in table 2.1, spin-offs and start-ups are not going to be included in this section as the number of spin-offs working in agricultural biotechnology in the Netherlands and the UK – and probably within EU in general - is very limited. While there are spin-offs using agricultural biotechnology techniques, they mainly work in medical and food related industries[6].

[6] A presentation by Jan Chojecki (Plant Biotechnology Limited’s Managing Director), gives six

The importance of different channels varies according to the nature of knowledge to be exchanged, or the participants engaged in these relations. In terms of codified knowledge, several studies indicate that publications are one of the most relevant and frequently used channels of knowledge exchange (Scott et al. 2001.; Agrawal & Henderson 2002; Cohen et al. 2002; Fontana et al. 2006; Brennenraedts et al. 2006). Along with other authors, Bekkers and Bodas Freitas confirm that patenting is among the least important channel of knowledge transfer[7] (Bekkers and Bodas Freitas 2010: 1849). Nevertheless, as will be discussed in Chapter 7, commercial activities such as patenting are still perceived to be an important mechanism of technology transfer by government.

Another important channel of knowledge transfer is the movement of students, staff and industry members between university and industry. As discussed in the previous sections, knowledge consists not only of codified knowledge but also of tacit knowledge, often embodied in people and organisations[8]. Therefore the exchange of knowledge cannot be conducted only through the channels of publications, patents and the like.

Regarding the view of participants of university-industry relations and the importance they attribute to particular channels, D'Este and Patel analyse the perspective of researchers' involvement, and their results show that academics are more engaged in activities such as consultancies, contract/ joint research or training compared to other activities such as patenting or spin-outs (D'Este and Patel, 2007: 1295).

Some scholars have looked at the factors that affect university-industry interactions, which, as the empirical chapters will show, are relevant within this dissertation as well. These factors include the R&D strength of the specific

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examples of the spin-offs their company has managed and only one of these works in the field of agriculture, while the rest work in medical related fields (Chojecki 2008)

[7] Throughout this dissertation, 'knowledge exchange' is the preferred term to be used rather than 'knowledge transfer'. However, the term 'knowledge transfer' is used when there is a reference to the work of other authors who have originally used the term 'knowledge transfer' in the referred work.

[8] OECD (2001) defines human capital as the sum of knowledge, skills, resources and competencies of individuals, which includes tangible elements such as physiological condition and health as well as more intangible elements such as cognitive capabilities and procedural capabilities (David 2001).

industry, the size of the firms, the science policies of the countries and so on. I have discussed in the previous section how I will use concepts from the sectoral innovation systems literature to show the sector-specific characteristics and how they affect university-industry relations (UIR). The literature on UIR also points to sectoral differences. Several authors have compared different sectors in terms of the intensity of their interactions, finding dense linkages in biotechnology as well as other sectors such as electronics (Faulkner and Senker, 1994). Faulkner and Senker argue that the nature of innovation differs across sectors; for example, in pharmaceuticals, they argue that it is closer to the classical linear model (1994: 688). While the high science content of the sector is an important factor explaining this, there are also other reasons. A study by Grupp et al. (2004) looks at the citation of academic publications in patents, and ranks technology fields according to the scientific references, with fields like biotechnology, pharmaceuticals and chemicals having large numbers of scientific references. While academic citations within patents do not prove direct links, as pointed out by certain authors (e.g. Meyer 2002), biotechnology is considered to be a research-based discovery process (Granberg and Stankiewicz as cited in Jacobsson 2002). Schartinger et al. (2002) write that sectoral variations in patterns of knowledge interaction should be expected due to factors like the technological proximity between the field of science and the sector of economic activity and whether the industries rely on radical or incremental innovations (p.307). Bekkers and Bodas Freitas' study of Dutch industrial and university researchers in four sectors suggests that "differences in importance of various channels of knowledge transfer are not related to (industrial) sectors as such" (2000: 1848) and they present three factors that appear to be more relevant: basic characteristics of the knowledge in question, the disciplinary origin of the knowledge, and individual and organisational characteristics of those involved in the transfer process (Bekkers and Bodas Freitas: 2008). We will show that, while this may be true, based on the case of biotechnology, where the application to medical and agricultural industries differs considerably, the industry side has just as much importance as the disciplinary origin. In addition to differences across sectors, Brannenraedts et al. (2006) write that there are sources of variety within a sector as well, related to the characteristics of the individuals involved in these relations, such as their reputation, position and level of specialisation.

Different firm-level characteristics such as the existing knowledge base and firm size are shown to affect university-industry relations (UIR). In terms of the existing knowledge base, Faulkner and Senker show that the UIR are likely to be greater when a technology is new to a firm and the firm does not have an existing knowledge base regarding that technology (1994: 691). Fontana et al. show that firms with intense R&D activities are more likely to get involved in collaborative activities with PROs (2006: 321). Laursen and Salter show that firms that have a more 'open' search strategy, meaning that they use a variety of knowledge sources, are also more likely to use university research more intensively (2004).

Firm size is also considered to be a factor that affects the range and scale of university-industry relations according to some scholars in the field. Based on different surveys, Cohen et al. (2002), Mohnan and Hoareau (2003) and Fontana et al. (2006) all show that larger firms are more likely to engage in collaborations with public research organisations. Bekkers and Bodas Freitas confirm that small firms are less inclined to engage in collaborative and contract research due to their limited financial and skill resources (2008: 1847). Rosenberg (1990) shows that generally it is large firms that are able to commit to basic research given its long-term nature. However, studies show that in high-tech sectors such as biotechnology small firms are also involved in basic research close to the commercialisation stage due to advantages such as first-mover advantages (Rosenberg 1990). In Chapter 7 the reader will see that firm size matters in agricultural biotechnology as well.

At a more individual level, Bercovitz and Feldman find that researchers in institutions where technology transfer is common and successful are more likely to disclose their inventions (2004). They add that researchers are again more likely to disclose their inventions if the department chair is active in technology transfer activities.

Motivations and barriers

For firms, the main motivations behind engaging in university-industry relations include reducing the commercial risks in more fundamental areas of research, early access to knowledge, access to skilled human resources, building absorptive capacity and cost reduction. For universities, these include mainly securing additional funding, and insight into the problems encountered by industry, which can stimulate new research areas.

Cervantes (1998) argues that firms enter R&D partnerships to overcome market failures associated with uncertainty, resource constraints and appropriability issues. While this may explain part of the reasons behind the links, other scholars have shown that there are more complex reasons as discussed in the next paragraphs.

Bonaccorsi and Piccaluga (1994) write that based on the market failure rationale, firms should engage in relations with university to get access to basic knowledge where incentives for firms to invest in it themselves are too low. They add, however, that this view is changing as the contributions from the academic literature show that there are multiple reasons for firms to engage in such relationships, such as building internal research capabilities that would allow firms to identify and exploit external opportunities.

Cohendet and Meyer-Krahmer write that “appropriation is not the only incentive for knowledge production” and there are other incentives for firms to invest in R&D such as being on the technological frontier, gaining reputation, building an absorptive capacity, and access to networks (Cohendet and Meyer-Krahmer, 2001: 1575). Blumenthal et al. (1996) also highlight that access to knowledge and skilled human resources is a more important reason for industry to engage in research relationships with academic institutions than to gain immediate commercial value (p.370). Nevertheless, there are also contrasting views; Brennenraedts et al. (2006) write that the motivation for companies to be active in R&D is mainly based on economical reasons and for it to be useful for industry, research has to be applied (p.7). The results of the empirical work carried out in this dissertation suggest that companies are indeed interested in research that is not necessarily readily applicable, as will be shown in Chapter 5.

In addition to institutional motivations, some studies have looked at individual motivations behind engaging in university-industry relations, some of which resemble institutional motivations. Owen-Smith and Powell (2001) look at faculty members' decisions to engage in patenting (in physical and life sciences) and find that proprietary and relational benefits are the two most important incentives. The same study also presents some disincentives such as frustrating relations with technology transfer offices. Tartari and Breschi show that access to financial and non-financial resources are reasons for academics to increase their collaboration with industry (2009: 2). The study by Baldini et al. on 208 Italian academic inventors shows that prestige, reputation and new stimuli for research are among the reasons for engaging in patenting, where personal earnings do not play an important role (2007). In a study of UK investigators in physical and engineering sciences, D'Este and Patel find that the main reason for academics to engage with industry is to 'further their research' but not to commercialise their research (2010). They add that the motivations also change depending on the channel of engagement; patenting and spin-offs are motivated by commercialisation, while collaborations are motivated by research-related factors (such as learning, funding, and in-kind resources). On the other hand, there are variations in motivations across disciplines as well; D'Este and Perkmann report from other studies that while the reason for engaging in patenting is motivated by income in life sciences, it is used to develop relationships with firms, or to access equipment or other opportunities in physical sciences (2010: 5).

Goktepe-Hulten and Mahagaonkar's paper on scientists affiliated with the German Max Planck Society suggests that scientists engage in commercialisation activities and use disclosures as "signals to gain reputation [rather] than financial benefits" (2010: 401). They also point out that there might be differences between the expected benefits of TTOs and individual academics, where the former are more interested in monetary benefits than the latter. Interviews conducted for this dissertation also point to instances of this mismatch, as will be shown in Chapter 5.

One of the major barriers to interactions between university and industry relates to the cultural differences between these institutions. Traditionally, universities are organised around the norms of 'open science' where the scientific community has been self-governed and where disclosure of results has been related mainly to reputation rather than economic gains. Publishing is the main means of reputation as well as promotion. On the other hand, the main motivation of firms is profit-making. Clashes between the openness and closeness of the systems, the time frames of research and other factors are common differences between university and industry. Salter et al. (2009) refer to these differences as 'orientation-related barriers'. They show that previous experience and inter-organisational trust lower these types of barriers. While the organisation of two systems is intrinsically different, they are not independent from each other. Nevertheless, as explained in the next section, some works such as those on the Triple Helix model argue that these systems are increasingly taking each other's roles.

Salter et al. refer also to 'transaction-related barriers' referring to "conflicts over IP, and dealing with university administration" (2009: 2). These conflicts have been previously discussed by Siegel et al. (2003) in relation to the organisational practices of TTOs. In a study of the Advanced Technology Programs in USA, Hall et al. (2001) demonstrate that IP issues between firms and universities are more likely to occur when the research results are likely to be less appropriable and when the research is of a short-term nature. Salter et al. (2009) argue that transaction-related barriers are more difficult to mitigate and are affected more by government policies. It will be shown in chapter 7 that especially in the case of UK there is indeed an observed parallel between the government's focus on commercialisation and complaints related to such transaction-related barriers.

The barriers to interaction between university and industry may also arise from a change in the missions *within* the university. It can be argued that within industry the mission is roughly the same at all levels from individual to corporate, which is – in very simple terms - to innovate. However, at the university level, significant differences can often be observed in the missions. As mentioned previously, commercial activities are not the priority of individual academics while they are for university technology transfer offices. Therefore, in addition to conflicts between university and industry, conflicts within the university between units such as TTOs and individual academics can cause drawbacks in university-industry relations, especially in cases involving TTOs.

Within universities, reasons for engaging in interactions with industry can change according to the unit of analysis as has been discussed above. We have seen that individuals may engage in such interactions for reputation, departments for materials, TTOs for money, and governments for reasons of accountability. The breadth of motivations can make it difficult to manage the interests of different parties and indeed conflicts between different actors within the university system have been observed in this study as well, which are discussed in chapter 5.

It has been shown in this section that there are several reasons as to why universities and firms engage in university-industry relations (UIR), which are broader than the justifications that can be explained through the market failure concept. Similarly, factors and barriers that affect UIR address a large number of issues. With these considerations in mind, the next section will discuss the macro-level reasons that have contributed to the intensification of UIR and will focus on the discussion of the role of universities.

2.2.2 The changing role of universities

Metcalfe argues that universities have always been a source of new inventions and new understandings, and therefore have contributed to wealth, but what is new and problematic is the expectation that they should become "direct vehicles of exploitation" (2010: 6). In this section I will discuss the reasons for this shift as well as some conceptual models that emphasise this new direction.

Universities have enjoyed a period of generous government funding following Vanevar Bush's "Science: The Endless Frontier", where basic science was heralded as the driver for innovation. Nevertheless, universities are not currently enjoying as much autonomy and their relations with industry are considered to be intensifying, due to a number of factors. In this section, I will review the drivers for this intensification and discuss whether this has resulted in a new type of university or whether universities have taken on new roles in addition to their traditional roles of teaching and research.

Senker (1998) uses the notions of supply-push and demand-pull for explaining increased university-industry links. In terms of supply-push, she argues that the government has not been able to sustain growth in research expenditures, which then led to universities looking for non-government sources of funding. In terms of demand-pull, intensifying competition for industry increased the need for more innovation, and in the case of science-based areas the need to be closer to the source of knowledge. Similarly, Rothaermel et al. (2007) provide two main reasons for increased university entrepreneurship: technology-pull from industry due to universities being a key source of innovation, and technology-push due to reduced public funding for research. In addition to budget cuts and the development of fields of science with high applicability, Geuna adds that another reason for the intensification of university-industry relations is the policies aimed at "raising the economic returns of public financed research…with the goal of increasing the transfer of knowledge from university" (1999: p.4). Finally, in addition to these, the emergence of science fields such as biotechnology where the science base is much closer to application has resulted in more mutually beneficial interactions between university and industry.

Two of the arguments Pestre (2000) presents regarding the changing role of universities are worth mentioning here to draw attention to the political factors as well. First of these is the economic change brought about by increased competition and open markets. Secondly, he points out an ideological change towards ultra-liberalism, encouraged by Reagan and Thatcher, promoting the "disengagement of [the] state from economic and techno-scientific activities" (p.179). In the case of the UK, the implementation of such an ideology has been observed with the gradual removal of government from much near-market research.

The intensification of university-industry relations has highlighted one of the missions of universities - perhaps disproportionately - over the others, which is the wider contribution to the society. While the contribution to society is the main reason for the existence of universities, first through teaching and then through research, the last few decades have seen the distortion and reduction of this mission to 'contribution to the (knowledge) economy', causing tensions for universities especially when it comes to the definition of these contributions.

Before going on to discuss these so–called new missions or roles, it is necessary to remind ourselves of the variety of ways in which universities have contributed and still continue to contribute to society. Universities have been considered to provide a number of benefits for industry through several mechanisms, as the literature shows. A report by Salter et al. (2000) identifies seven benefits that flow from publicly funded research: increasing the stock of useful knowledge, the supply of skilled graduates, the creation of new instrumentation and methods, development of new networks, enhancement of technological problem-solving capabilities generation of new firms, and the provision of social knowledge. Geuna summarises the contribution of university knowledge to industry under three main headings; in the form of inputs for knowledge creation at industry; through the dissemination of research results; and finally through cooperative R&D projects (Geuna, 1999: p.3). It can be seen from this variety of channels that any theory or policy reducing the contribution or role of universities to a direct economic contribution would be under-utilising the resources of universities. In the following section, two bodies of literature related to universities will be critically discussed: the New Production of Knowledge and the Triple Helix model.

New Production of Knowledge

The main argument raised in the 'New Production of Knowledge' (NPK) (Gibbons et al., 1994) is that there has been a shift from Mode 1 to a new Mode 2 form of knowledge production. According to the authors, Mode 1 is produced in the academic context; it is autonomous, disciplinary, homogenous and hierarchical, and it does not have much social accountability. In contrast Mode 2 is claimed to be trans-disciplinary, non-hierarchical, heterogeneous, not primarily institutionalised in universities and more socially accountable.

Alongside with Pestre (2000), Martin and Etzkowitz (2000) argue against this claimed shift and they write that Mode 1 and Mode 2 both existed before but there may be a change in the balance towards Mode 2. They note that inter-disciplinarity, the context of application and the blurring of institutional boundaries have all existed in the past and they, too, are not new, but are perhaps moving to the forefront of attention again (p.28). In addition to the historical problems pointed out by the authors, there are several other problems associated with some of the arguments in the NPK.

It is argued in NPK that within Mode 1 problems are set and solved mainly according to the interests of the academic community, whereas in Mode 2 knowledge is produced in a context of application, not necessarily being restricted to the knowledge needed for product development but also including knowledge having a broader utility to someone. While academics may have enjoyed a period of autonomy in directing their research based on scholarly interest rather than according to the priority areas set by governments, it would be simplistic to assume that these interests have not benefited society.

Another claim made by the authors of NPK is that 'technology transfer', a Mode 1 concept, is a result of "lack of interest and investment in distributing research results", which led to the institutional separation of universities and government research establishments, which in turn required moving knowledge across boundaries (p.51). While the authors do not provide any empirical evidence to back this claim, it is debatable whether the 'Mode 2' knowledge is any better in breaking the boundaries as the policies are still concerned with the transfer of knowledge between boundaries, i.e. universities and industry.

Finally, the last claim to be debated from the NPK model is the contribution of universities to knowledge production. While the authors are correct in arguing that universities are not the only loci of knowledge production, their statement that "…the universities, in particular, will comprise only a part, perhaps only a small part, of the knowledge producing sector" (Gibbons et al., 1994: 85) is far from verifiable. Godin and Gingras's (2000) bibliometric study based on academic papers concludes that, on the contrary to playing a small role, universities are actually at the heart of scientific knowledge production.

Pestre criticises the NPK model by arguing that the authors have "underestimated the extent to which these transformations [from mode 1 to mode 2] have been the results of political and social *choices*" (2003: 246) and that the developments are not cases of natural evolution.

Although the New Production of Knowledge has raised interesting debates regarding the role of universities in society, the empirical evidence underlying the descriptions and prescriptions it has offered are questionable, and it does not present a full account of the transition that universities are undergoing.

The Triple Helix model

The Triple Helix model (TH) was put forward mainly by Etzkowitz and Leydesdorff in the mid-1990s. The main argument of the model is that university and industry have traditionally been in separate institutional spheres but they are now taking on each other's roles as well, with the inclusion of the government as the third sphere. The authors talk of a "new social contract for university" (Etzkowitz & Leydesdorff, 1995) and of a 'second academic revolution' integrating "a mission for economic and social development" into the traditional functions of the university, which are teaching and research (Etzkowitz, 2004). Martin and Etzkowitz (2000) argue that the 'entrepreneurial university' is not an entirely new concept and universities have cooperated with industry in the past as well.

Leydesdorff and Etzkowitz (1998) present three stages of TH. In the first model of TH, there are three distinct spheres and the interaction between them is mediated by organisations such as industrial liaison and technology transfer offices. In TH II, these spheres are considered as different communication systems, and finally it is claimed by the authors that in the last TH model, the three institutional spheres assume each other's roles as well as performing their traditional functions. There are two issues that are debatable about the different TH models proposed. Firstly, a good number of triple helix studies focus on intermediary organisations such as science parks, TTOs, ILOs and so on, of which some are arguably organisations that work on the TH I model. Secondly, the extent to which the different spheres can take on each other's roles is questionable. While it is true to a certain extent that universities are increasingly involved in business creation through spin-off and start-up firms, they do not have the power of drawing up legislation, for example, this being a government role.

Geuna and Muscio argue that, while the involvement of universities in knowledge transfer activities is not a new phenomenon, as suggested by the NPK or TH models, what is new is the 'institutionalisation' of university-industry links (2009: 94). What is meant by institutionalisation is the governance of knowledge transfer activities by the direct involvement of university. They add that the institutionalisation is limited to only a number of university-industry interaction channels.

Another critique of the TH model comes indirectly from Kaufmann and Todtling, who argue that, while the boundaries between universities and firms might be blurring as *organisational* types, the *systems* they operate in – namely, 'science' and 'business' - are quite distinct (2001: 795). It can also be suggested that the presence of cultural and language barriers mentioned in the previous sections (and also identified in the interviews conducted for this study) support the argument of there being different systems.

Further detailed critiques about the NPK and TH can be found in the works of Shinn (2002) and Hessels and Van Lente (2008).

The main problems of both bodies of literature mentioned above is that they tend to confine the role of universities to an 'either/or' state. On the contrary, policies should take into account the variety of channels through which universities can contribute to society as well as the economy. As Jongbloed et al. argue, "…the contemporary university suffers from an acute case of mission confusion" and as a result it sub-optimally allocates its human and physical capital (2008: 304). The last section of this chapter will argue that, in order to understand this broad contribution from university to both economy and society, there is a need to extend the discussions of university-industry 'technology transfer' to 'knowledge exchange' between university and industry, where the former is a more restricted view, while the latter encompasses the full breadth of university-industry relations.

2.3 From 'Technology Transfer' to 'Knowledge Exchange'

The term 'technology transfer' is used in a number of contexts including the transfer between countries and firms as well as that between university and industry. This section will focus on the latter.

In the previous sections, we have shown that there are a variety of channels through which university-industry relations take place. I will argue in this section that the notion of 'technology transfer' underlies only a small part of these channels such as patents and licenses. Therefore, in order to understand the whole spectrum of university-industry relations, there is a need for a broader notion, which I suggest should be 'knowledge exchange'.

Salter et al. argue that a differentiation should be made between "information as a commodity and knowledge as the capability to use information", and that the view of publicly funded research being reduced to information undervalues the skills embodied in people and their networks (2000: 7). It was also mentioned in previous parts of this chapter that knowledge and information differ, where the former involved tacit components as well as codified ones. Freeman writes that the original meaning of the word 'technology' refers to "a body of knowledge about techniques" (Freeman 1977: 225). In this sense, it is broader than the definition of information. On the other hand, the same definition is also constrained to particular techniques. While transfer of technology in this broad sense would be a desirable outcome of university-industry relations, it falls short of encompassing the broader set of skills that can flow between the two institutions.

According to the Oxford Dictionary, the word transfer means "move from one place to another". It is well established in the literature now that in contrast to information, knowledge cannot be easily moved due its tacit nature. It was shown in the previous sections that, although there are channels of university-industry interactions such as patenting and licensing that involve the movement of information, these are among the least important knowledge sources for industry.

Friedman and Silberman defined technology transfer as "the process whereby invention or intellectual property from academic research is licensed or conveyed through use rights to a for-profit entity and eventually commercialised" (2003: 18). As this definition demonstrates, 'technology transfer' is a one-way street based on a linear model of innovation. It assumes that technology is generated in the research institutions and that it should be transferred to industry for a commercial application. The idea of a transferrable technology is based on the assumption of technology being reduced to codified knowledge, or information.

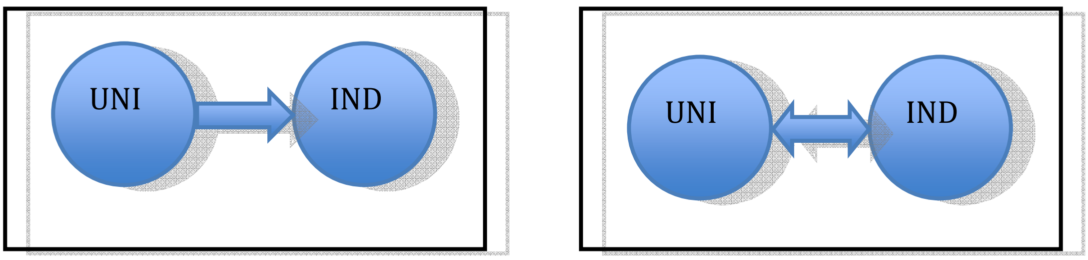
Harmon et al. argue that studies on university-industry technology transfer fall into two philosophical perspectives; those that consider technology transfer as a buy-sell transaction, and others that consider it as a collaborative activity within a network of formal and informal relationships (1997: 425). As will be shown in the next chapter, the two perspectives suggest different channels for improving university-industry relationships, including the intermediaries. Technology transfer organisations are the best example of the first type of perspective. The first perspective can also be observed in the policies of governments in relation to stimulating university-industry relations, which will be discussed empirically in Chapter 7.

Other authors have also criticised the notion of 'technology transfer'. Meyer-Krahmer and Schmoch (1998) argue that the term 'technology transfer' should be replaced by 'knowledge exchange' to account for a bi-directional flow between university and industry. Their findings show that industry conducts a significant amount of research, which is also of interest to the academic community, suggesting bi-directionality (ibid, p.842). They follow on from this argument to write that consequently the policies should change as well to be transformed into policies with a 'two-way bridge' concept (p.848).

Lockett et al. (2008) define knowledge transfer as "the two-way transfer of ideas, research results, expertise or skills between one party and another that enables the creation of new knowledge and its use" (p.664), and they represent technology transfer as a subset of it.

Overall, the 'technology transfer' implies a one-directional flow of codified knowledge from university to industry (figure 2.1a) where as 'knowledge exchange' implies a bi-directional flow of codified and tacit knowledge between university and industry (figure 2.1b) that can happen through a multiple number of channels.

Figure 2.1: Technology Transfer vs. Knowledge Exchange



(a) Technology transfer (b) Knowledge exchange

2.4 Summary and conclusions

In this chapter I have discussed the main framework of this dissertation, which is the systems of innovation framework. After introducing the building blocks of the systems of innovation framework in section 2.1.2, I have argued that the most suitable systems framework for addressing the research questions of this dissertation is the national one (section 2.1.3). I have then focused on a particular part of the system: universities, industry and the links between them. In section 2.2.1 I have briefly described the motivations, channels, factors and barriers surrounding university-industry relationships with the aim of later comparing the results of my empirical findings with the current literature. Section 2.2.2 discussed whether there is a changing role for universities by presenting the two main bodies of relevant literature and the arguments against these.

In the next chapter I will analyse the literature on specific intermediary organisations according to the functions they carry out, and then proceed to suggest four theoretical intermediary types based on these functions. I have shown in this chapter that there are various channels of university-industry interaction ranging from formal to informal, tacit to codified and so on. The functions that are discussed in the next chapter are based on these characteristics. I have also discussed in this chapter the changing roles of universities. I will further emphasise in the next chapter that some of these intermediary types are based on these changing notions.

CHAPTER 3: INTERMEDIARIES - WHAT DO THEY DO? WHAT CAN THEY DO?

The previous chapter has focused on the literature on the systems of innovation framework and on university-industry relations. It has pointed to the problems of the market failure rationale and supported the need for replacing it with a systems failure one. It was also argued that within a systems failure rationale, the concept of 'technology transfer' needs to be replaced by one of 'knowledge exchange', stressing the bi-directionality and non-linearity of the process involved.

In this chapter, the broader activities within the knowledge-exchange structure will be discussed in relation to the role that intermediary institutions can play. Intermediary organisations such as technology transfer offices, science parks and the like have often been regarded as mechanisms for facilitating technology transfer. There have been many studies carried out regarding intermediary organisations in general and for more specific types too, yet the literature remains rather fragmented. One of the contributions of this dissertation will be to make an attempt to synthesise this literature through the use of different roles of intermediary organisations with regards to the knowledge exchange process.

The main goal of this chapter is to build a conceptual framework for the analysis of intermediary organisations. It is useful to briefly give the rationale behind this framework in this introduction before going into its background and specifics. The perception of intermediary organisations as facilitators of the technology transfer process suggests the existence of a problem and, as will be explained later in the chapter, a common problem is converting the outputs from the science base into innovative products. This is based on a linear view of innovation, where a disruption occurs during the process starting at basic science and ending at application. As stressed in the previous chapter as well, I argue that this is a narrow approach to the problem and is not sufficient in capturing the broader set of problems in the system these processes are embedded in. I suggest that the problems for the case of knowledge-exchange process between university and industry are the various barriers between the two sectors, and that solutions to this problem – intermediary institutions in this case - should overcome these barriers.

I will propose that these institutions can play certain functions with respect to overcoming the existing barriers, and therefore the assessment of intermediary organisations should be based on the extent to which they fulfil these roles, instead of relying solely on assessments based on more readily available quantitative indicators.

Section 3.1 briefly reviews the existing generic literature on intermediary organisations for innovation according to five main roles; transfer, transaction, transformation, translation and facilitation. Section 3.2 moves on to review the most common types of specific intermediary organisations, relating them to the five roles mentioned above. Section 3.3 makes a synthesis of these roles and the existing organisations, and proposes four idealised types of intermediary organisations. Based on the existing university-industry interaction channels, section 3.4 puts forward five functions that intermediary organisations can play within the knowledge exchange process. A summary of the conceptual framework is presented in section 3.5.

3.1 Intermediary organisations in innovation – the broader literature

The term "intermediary organisation" is widely used not only in innovation studies literature but also in the fields of IT, finance, and so on. In this dissertation, the various terms intermediaries/intermediary organisations/intermediary institutions refer to those structures located between university and industry and taking part in the technology transfer/ knowledge-exchange process[9]. However, this definition is too broad and can theoretically include organisations related to administrative, financial and legal aspects related to the knowledge-exchange process as well, which is not the main concern of this dissertation. Instead, the discussion will be limited to intermediaries related to the 'hard' functions of knowledge exchange rather than the 'soft' ones.

Different authors define intermediaries in varying ways. Van Lente et al. (2003) describe knowledge intermediaries as "organisations or arrangements that

[9] I will mainly use the term 'intermediaries' in this chapter for the sake of simplicity, leaving an elaboration of the differences between an intermediary organisation and an intermediary institution to be made in the analysis chapters.

connect two or more actors and support them with their innovative activities" (p.3). Mason and Wagner (1999) write that intermediates refer to "organisations and programmes which have the designated role of 'bridging the gap' between private industry and science base institutions" (p.86). Den Hertog et al. (1995) write that the role of intermediaries can potentially be "to bridge the gap between the enormous resources of supply and the dense and the varied population of users" and more specifically "to translate the problem of the user into a solution in terms of knowledge or technology, to match users with the appropriate technology available or to increase awareness of the benefits of the use of certain technologies" (p.15). The common assumption underlying these various definitions is that there are two worlds with problems in working with each other - partially or wholly - and intermediaries help to solve these problems through 'bridging the gap'.

While it is acknowledged that intermediaries help facilitate the relations between the two worlds, university and industry in this case, it is questionable whether this is a problem of 'bridging'. As has been shown in the previous chapter, while university and industry are distinct institutions with different sets of goals and characters, they do interact naturally and are not completely separate. Therefore, it can be argued that the intermediaries have the potential to play a 'catalysing' role more than a 'bridging' one for university-industry relations. While bridging implies connecting previously disconnected organisations, catalysis would refer to creating the conditions that would facilitate the interactions between organisations that are already connected.

The following paragraphs will break down the 'bridging' or 'catalysing' processes through a brief review of the literature. I am going to present the roles that intermediaries play – as studied by different authors - under five main roles that I consider these organisations play; four are related directly to the knowledge exchange process – transfer, transaction, transformation and translation - while the fifth heading – facilitation - covers the other roles.

The first group of roles can be classified under the heading of *'transfer'*, where intermediaries serve a role in the flow of information across domains. As Howells (2006) writes, agricultural extension agencies have traditionally been responsible for the diffusion of information through informing farmers about new technologies available in the field. Wright et al. (2008) adopt a 'transfer' approach when they argue that intermediaries are 'boundary-spanners' that "take knowledge from one domain and move it to be applied in another" (p.4). These intermediaries can vary in form; technology transfer offices, science parks, incubators, venture capital firms and so on. The difference between the two examples is that while the first one is about the diffusion of information, the second one is about knowledge flows. We have seen that knowledge is not readily transferable due to its complex nature and its tacit components. Therefore, it can be argued that intermediaries as described by Wright et al. (2008) are based on a linear model of innovation and that this approach is therefore questionable.

Intermediaries associated with *'transaction'* are also involved in the movement of information rather than knowledge, but there is an obvious monetary element to the role they play. This can be done explicitly through defining monetary components of the relationship between university and industry or more implicitly through a reduction of the costs associated with the relationship between the two sectors. Howells (2006) writes that intermediaries can formalise the informal relations through contracts and licenses. Shohet and Prevezer write about a similar role in terms of administering "activities relating to certain types of codified knowledge" (1996: 292). Hoppe and Ozdenoren (2005) argue that innovation intermediaries such as TTOs reduce the uncertainty problem faced by the firms when confronted with an investment and the uncertain value of the technology they are interested in. It can be said that in both examples intermediaries help in establishing monetary components in the relationship between university and industry. It will be shown in Chapter 5 that this is indeed a role played by intermediaries, but whether it facilitates or hampers the relation is dependent on the experience of the intermediary. On a more implicit level, Kodama regards university-industry intermediaries as "entities that reduce search costs and bargaining costs for the firms and universities that are seeking collaboration partners" (2008: 1226).

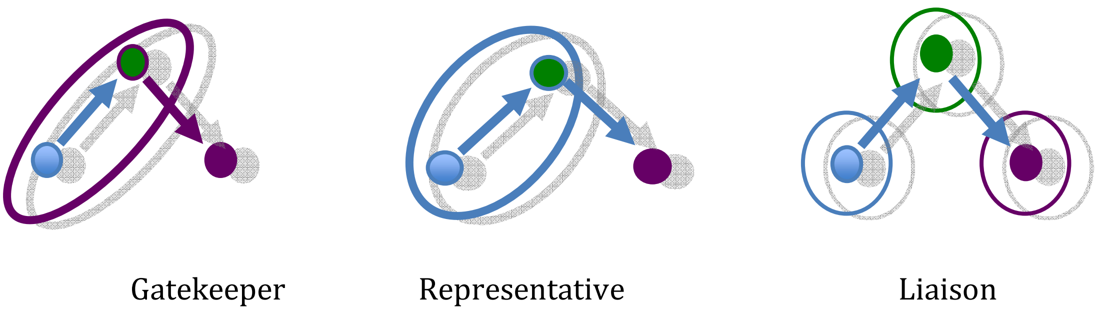
Based on the literature reviewed here, a third group of roles that intermediaries can play can be grouped under the heading of *'transformation'*, where the intermediary does more than merely transferring information. An example of this role is a technology broker as described by Hargadon and Sutton (1997), which has an "organisational memory that allows it to acquire, retain and retrieve new combinations of information" obtained through its position in the network (p.717). Referring to previous literature, Hargadon refers to brokers as social actors that occupy positions "spanning otherwise disconnected subgroups" and who can bridge multiple fragmented domains and move ideas (2002: 44). A similar role is described by Bessant and Rush (1995), in reference to what they call 'systems integrators', who can ferret out and provide technology for the receiver from a multitude of sources and make new combinations when necessary.

One step further than transformation is the role of intermediaries that would go under the heading of 'translation'. This category is based on studies that consider university and industry as two separate worlds that need a translator in between. Kaufmann and Todtling (2001) write about translation through bridges in relation to university-industry relations. They argue that the barriers between university and industry are caused by systemic differences, and that the reduction of these barriers should occur through bridges rather than trying to change the system characteristics, as they claim that diversity stimulates interactions in the first place. They define bridging as "making one system's operation understandable and, thus, its output usable for another system", a process which one needs to "translate system-specific rules and ways to communicate" and "contribute to make the different operational principles compatible" (Kaufmann and Todtling: 802). It can be argued that the translational approach would be in contrast with the Triple Helix model discussed in the previous chapter, where it is assumed that university and industry are increasingly overlapping in the roles they play. Within such a framework there should not be a need for intermediaries to play a translational role, as they would not be considered as two separate systems.

In addition to the knowledge-related roles that intermediaries can play, there are further studies in the literature that focus on other roles that can be grouped under networks and facilitation. These roles include connecting actors or facilitating the relations between already connected ones. An example of a network role is given by Sapsed et al. (2007), who write that bridging organisations have a structural role of "connecting otherwise disconnected communities of people, organisations and resources" (p.1315). As will be shown in the next section, this is one of the characteristics of industrial liaison offices. On the other hand, Shohet and Prevezer conclude that the role of intermediaries in "initiating informal and tacit linkages" is limited, as members of university and industry prefer more direct communication channels (1996: 292). In presenting the empirical findings, Chapter 5 will support this result as well.

In terms of *facilitation*, a study by Gould and Fernandez (1989) identify five types of mediation based on the positioning of what they call transaction parties and brokers. Quoting Marsden (1982), they define brokerage as a process "by which intermediary actors facilitate transactions between other actors lacking access or trust in one another". Of the five types of mediation structures they present, the first is limited to mediation within the same subgroups, which is not the focus of this dissertation. The second two are what they call the *gatekeeper* and *representative* roles, where the broker belongs to the initiator subgroup in the former and to the receiver subgroup in the latter, as depicted in figure 3.1. Finally in the last mediation structure, *liaison*, the broker does not belong to any of the subgroups, which do not know each other.

Figure 3.1: Mediation structures as defined by Gould and Fernandez (1989)



For the gatekeeper and representative type structures, a good example would be university TTOs, which can be one or the other, depending on whether they approach the firms or the firms approach them. For the liaison function, sectoral technology-transfer companies, which will be described in Chapter 5, represent an example.

3.2 Intermediary organisations – specific types

In the previous sections the generic literature related to intermediaries in innovation has been reviewed and synthesised in terms of the functions that intermediaries can have with regard to knowledge and information (transfer, transformation, translation and transaction) and to networks and negotiations. In this section, the literature on more specific types of intermediaries will be discussed, keeping in mind the above-mentioned roles derived from the more generic literature. This will also prepare the ground for the next section, where five types of intermediary structures are proposed based on the studies on more specific types of intermediaries.

The specific intermediary types discussed in this chapter will be limited to those located between university and industry, as this is the focus of this dissertation. It should be mentioned that the chosen types need to fit within an outline consistent for this dissertation and this may exclude certain organisations, which some readers might argue should be included. These organisations are limited to: public-sector research organisations; technology transfer offices and industry liaison offices; and science parks. Other organisations such as spin-offs and start-ups are deliberately excluded, as they are more concerned with new firm formation, the goal of which may or may not include knowledge exchange. In contrast, it can be argued that the intermediary types chosen for this section are more directed at facilitating exchange between existing organisations in academia and industry. While it is acknowledged here that new firm formation is another mechanism for knowledge exchange between university and industry, it is a field large enough – especially when coupled with entrepreneurship - to be included within the scope of this dissertation. Furthermore, as will be shown in Chapter 6, the agrochemicals, seeds and agricultural biotechnology sectors are dominated mainly by established firms and they differ from the pharmaceutical biotechnology sector in terms of a relatively low number of dedicated small biotechnology firms.

3.2.1 Public-sector research organisations

Public-sector research organisations (PSROs), transfer institutes, research and technology organisations or what are sometimes referred to as contract research organisations (CROs) in the literature, will refer here to research organisations other than universities that have or have had in the past considerable government funding in addition to working with industry for contract research. Some examples of PSROs are the Fraunhofer Gesselschaft institutes in Germany, TNO (Netherlands Organisation for Applied Scientific Research institutes) in the Netherlands, and currently a number of private ones in the UK such as the AIRTO[10] members. The details of the relevant Dutch and English PROs will be discussed in Chapter 6.

Webster (1994) defines contract research organisations as “public or private agencies or firms that undertake research and development activities for others as agreed by formal contract, normally in a competitive research market” (p.90). The most important feature of these organisations is that “they act as providers of R&D services to (typically industrial) clients by bridging between their clients’ specific technological needs and the wider knowledge base within which the CROs are located or to which they have strong links” (Webster 1994: 90). Giving an example from the Fraunhofer institutes, Braunling contends that these types of intermediaries provide an interface in a context where it is assumed that “research and industry are two social systems, characterised by different goals, award systems, orientations and constraints” (1990: 3; as quoted in Webster 1994: 91). Den Hertog et al. (1995) write that depending on the country, RTOs can play a role in “creating (specialised) basic knowledge”, “translating and transferring available knowledge and technical expertise into practical products and services for certain groups of users”, and “educating R&D personnel” (p.37). These examples would suggest that PSROs can play a transformation and/or a translation role.

RTOs in the UK have been referred to as ‘technology intermediaries’ in DTI’s 2003 report, whose functions include; supporting company innovation by providing expertise, translating raw knowledge into applications and work with universities through commercialisation activities. However, this is quite a broad definition and as will be discussed in chapter 7, the existence of RTOs varies across the sectors as well.

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[10] AIRTO (Association of Independent Research and Technology Organisations) is the umbrella organisation in the UK for individual, privatised research and technology organisation (Hales 2001). Members conduct a range of services from consultancy to testing and work across a number of industries.

Foray and Lissoni (2009) label similar organisations as "government research laboratories" where the government is directly engaged in the production of knowledge. The authors argue that the heavy reliance on these organisations is "a legacy of the past" where Western countries were building a science and technology infrastructure through these 'mission-oriented' organisations (Foray and Lissoni 2009: 9). It will be shown in chapter 7 that the scope for government research labs has been decreasing as argued by Foray and Lissoni, and these organisations play an important role in explaining the difference between the Netherlands and the UK systems surrounding agricultural biotechnology sector.

3.2.2 Technology transfer offices (TTOs) and industry liaison offices (ILOs)

The literature on technology transfer offices is large enough to deserve a section on its own, while in contrast the number of studies on industry liaison offices is much smaller[11]. More importantly, many of the ILO functions discussed in the literature are now absorbed within TTOs, which would further justify the inclusion of these organisations under this section.

The studies on ILOs indicate that their original mission was to act as a 'gateway' for industry to contact academics. Wald (1972) argues that ILOs in the UK were funded by the government to promote university-industry links. Fassin (2000) writes that ILOs play several important roles in the technology transfer process: "information broker, science marketer and catalyst for academic entrepreneurs" (p.35). More specifically, he considers promotion of university-industry links, and internal and external marketing as the main contributions that such an office can make. A more recent study by Bruns et al. (2008) on ILOs in the food sector attaches the roles of moderation, guiding, administrative support and similar 'soft' functions to these organisations.

While the footnote at the bottom of this page suggests that more studies are conducted on science parks than on technology transfer offices, it can also be argued that TTOs are likely to be more involved in university-industry relations than science parks. With increased funding, several universities now have TTOs in

[11] A quick search on Google Scholar using the phrase "industry liaison office" in the body of the text reveals 135 results compared with 1940 for "technology transfer office" and 9240 for "science park", limited to Business, Administration, Finance, and Economics and Social Sciences, Arts, and Humanities fields, and as of 20.04.2010.

place and these are involved in contractual arrangements between university and industry.

Issues of Efficiency

The literature on TTOs contains numerous studies on the efficiency or productivity of TTOs measured from different perspectives through different methods. However, these works are mostly rather fragmented in that they analyse a very specific aspect, and there is a lack of a systematic assessment of TTOs with regard to how well they fulfil their functions. As the aim of this study is to conduct a functional analysis of intermediary organisations, I will briefly review the literature on TTOs in relation to their roles, keeping in mind the groups of roles described in section 3.1.

With the increasing number of TTOs following the Bayh-Dole act, academics – mainly in the US - have started to question two related issues around patenting and licensing activities. One of these is whether the increase in patenting and licensing activities was due to the Bayh-Dole Act, and the other was the effectiveness and productivity of TTOs. For both matters, the use of patenting and licensing data is prevalent. As Rothaermel et al. (2007) noted, there are discussions in the literature as to what are acceptable measures of TTO productivity (p.58). Amongst these are some that consider the number of licensing agreements and revenues (Siegel et al. 2003; Chapple et al. 2005) while others consider invention disclosures and sponsored research agreements as alternative indicators (Friedman & Silberman 2003; Bercovitz et al. 2001) based on survey data. These are indicators that are more readily available in databases and hence relatively easy to quantify. Nevertheless, relying solely on the available indicators can be risky, as it may not allow one to capture the more tacit aspects of university-industry technology transfer. Therefore, in this dissertation a qualitative methodology will be followed to analyse the intermediary organisations, including TTOs, based on the functions they can perform. The next paragraphs will look at the academic literature on the roles of TTOs.

The roles attributed to TTOs in the literature are very broad. Markman et al. (2005) state that university TTOs function as ‘technology intermediaries’ that “transmit technological innovations from the lab bench to the industry” (p.242). In a similar vein, Wright et al. (2008) define the role of intermediaries as "to facilitate exchange between two (or more) transacting parties…through the provision of value-added services" (p.1206). While defining the role of TTOs so broadly would give them a flexible operating space, it can also cause problems by encouraging them to operate in areas in which they may not necessarily have the relevant competencies, as will be shown in the empirical chapters.

Other studies take a more narrow approach regarding the role of TTOs. Siegel et al. (2007) state that TTOs "serve as an intermediary" between scientists and those who can potentially commercialise their results and, as such, they facilitate the "commercial transfer of IP" (p.641), suggesting a transaction role. A similar result is presented by Colyvas et al. (2002), who write that TTOs have a role in patent applications as well as in protecting the university's interests in transactions. Placed within the principle-agent theory, Guston (1999) considers TTOs as boundary organisations with a translational role. It will be argued in chapter 8 that TTOs do not have a translational role according to the definition of 'translation' used in this dissertation.

There are also studies in the literature on the issue of which roles TTOs are not suitable for. One example regarding facilitation is given by Carr, who writes that the legal role of TTOs can be detrimental when overstated: "…lawyers in technology transfer are like the brakes on a car. You wouldn't want a car without them, but neither would you want the brakes to control the car's movement." (1992: 33). Another article by Colyvas et al. (2002) regarding networking argues that "...the auspices of that office mostly were not needed to make contacts with industry, to spread information, or to induce industry interest", but that their main role was in dealing with the complexity of the patenting and licensing processes (p.66). The differences between the results of the various studies suggest that the problem is deeper than whether TTOs have a role in a certain area or not. The empirical chapters will support this suggestion by showing that the context in terms of sector and national institutions is an important determinant in influencing how the TTOs perform a certain role.

3.2.3 Science parks

In this section, I will briefly analyse some of the studies on science parks[12] through the suggested roles they play as intermediaries between university and industry. This excludes some of the empirical studies on different aspects of science parks, such as the conditions for their formation and growth and their impact on local and regional economic growth.

Science park literature goes hand-in-hand with the incubator literature, also because many incubators are located on the park premises. As I explained at the introduction of this chapter, I will not focus on new firm formation and it is for this reason I deliberately exclude incubators. Again, it is acknowledged that they can play a role in knowledge exchange between university and industry, but this is another mechanism that cannot be studied within the limits of this dissertation.

Although it is difficult to clearly define what constitutes a science park, the United Kingdom Science Park Association defines a Science Park as “a business support and technology transfer initiative” that encourages start-ups of high-growth, knowledge-based firms, provides an environment where larger and international firms can develop links with “a particular centre of knowledge creation for their mutual benefit” and “has formal and operational links with centres of knowledge creation” (UKSPA, 2007). While they do not define what these mutual benefits are, they write that the technology support involves the associated knowledge-creation centre, business services that include ‘soft’ tasks as well as advice on IP, access to venture capital and so on. Based on these, it can be argued that they are mainly involved in transaction-related roles.

Van Dierdonck et al. (1991) write that science parks are part of a regional development ‘scenario’, where universities provide the information for the existing firms and also help the creation of new technology-based firms (NTBFs), and science parks ease the information flow through physical proximity with university and also through creating a collaborative network between the tenants. Lawton-Smith writes that the policy justification for increasing “territorially-focused university-industry interactions” is based on four explanations as to why

[12] Science parks are also known as technology parks, research parks, business parks and so on.

proximity increases the efficiency of the innovation process (2007: 101). These include: innovators being geographically concentrated, especially in the early stages of some industries; taking advantage of local knowledge spillovers; (transaction) cost advantages; and taking advantage of educated people coming out of universities. Studies that have looked at the role of geography for university-industry relations do not provide conclusive results[13], and while the literature shows that physical proximity is a positive factor, it is not essential. As the empirical chapters will show, the networks between universities and industry within high-technology sectors are not necessarily bound by physical proximity.

Studies on the reasons for universities to establish science parks indicate that they mainly involve transaction-related reasons. Westhead and Batstone (1998) argue that the following are among the main reasons: making their research more industrially relevant and securing external funding; commercialising the results of their research (through spin-offs in science parks); and providing additional income through rents, consultancy fees and employment of students and staff (p.220).

As in the technology transfer literature, some of the authors attribute translational roles to science parks. Van Dierdonck et al. (1991) mention that governments see science and industry as two different worlds that have a gap between them, and science parks are one of the technology transfer mechanisms that can bridge this gap. Massey and Wield (1992) also draw attention to the use of science parks as policy tools and quote the speech of Lord Young, Secretary for Employment in the UK, for the opening speech of the UK Science Parks Association in 1985: "Science parks have much to do with the wealth and job creation...I believe that one of the long standing problems in this country was the separation of the 'groves of academe' from industry and from wealth creation" (p.13). However, the literature remains sceptical about whether science parks fulfil these roles, and this is reinforced by the findings from this dissertation.

[13] For a more extensive discussion and summary of the literature on the role of geographical proximity for university-industry relations the reader can refer to Lawton Smith (2007: 106-108).

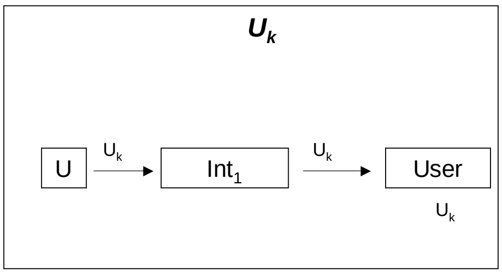
3.3 What types of intermediaries?

A key aim of this dissertation is to provide a conceptual framework for assessing the advantages and disadvantages of intermediaries in promoting knowledge exchange between university and industry based on the functions they can fulfil. One of the options to conduct such an assessment would be to go through different intermediaries – public research organisations, technology transfer offices, science parks and the like - and try to determine and prescribe what roles they should play. However, this has a drawback of limiting the research to already existing organisations, which would not allow one to capture possible new intermediary types. Furthermore, the nomenclature can be misguiding; not all technology transfer offices or science parks have the same composition or duties even if they are called a technology transfer office or science park. I will suggest an alternative in this chapter where I will propose five structures of intermediaries derived from the existing specific ones and keeping in mind the groups of roles presented in section 3.1. To remind the reader again, these roles were transfer, transaction, transformation, translation, and networks and negotiation.

Transporters

The first two groups of roles described in section 3.1 were transfer and transaction. While it is possible to find separate examples of organisations carrying out these roles (extension agencies and technology transfer organisations respectively), their involvement in knowledge flows is the same. Organisations conducting these roles are not active transformers or translators of knowledge and they transport information without changing it. The roles of transfer and transaction are therefore grouped under the same structure; the *transporter.*

Figure 3.2: Intermediary type- Transporter

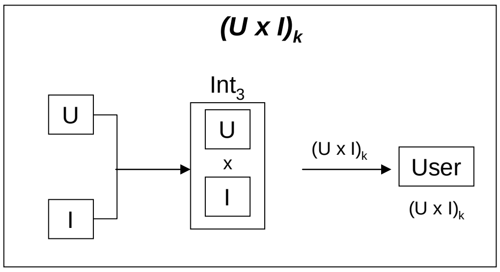


Hosts

Hosts are intermediaries that provide a setting for university-industry knowledge exchange and carry out a facilitation role without getting involved in the knowledge production process themselves. The difference between hosts and transporters is that in the former university and industry are kept separate and there is not much overlap. On the other hand, within a host intermediary, university and industry come together, at least geographically.

The main example in this category is the science parks, which is supposed to act as a catalyst for university-industry interaction through different mechanisms.

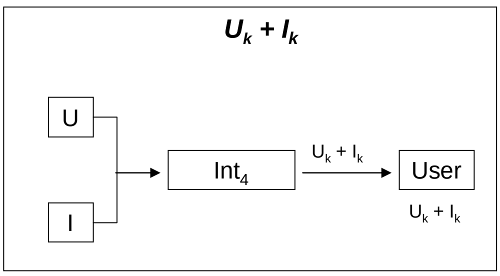
Figure 3.3: Intermediary type- Host



Transformers

This category of intermediaries is mainly based on the transformation role described in section 3.1, where the intermediary has the capabilities to ferret out knowledge from multiple sources and make new combinations to solve the problems of the user. In the generic literature, 'technology brokers' and 'system integrators' are given as examples of this type of intermediary. More specifically, consultancy firms are a good example of this category; they do not get involved in the knowledge creation process but also differ from transporters in the sense that they are able to add value during the process.

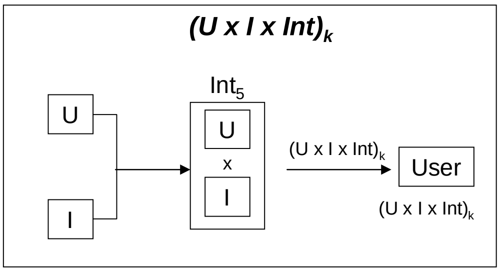
Figure 3.4: Intermediary type- Transformer



Translators

In this category, intermediaries are not only able to ferret out knowledge from a multiple number of sources but they also have the capability to get involved in the knowledge creation process itself. Examples to this category are the public-sector research organisations like the TNO institutes in the Netherlands, Fraunhofer Institutes and the like. In the most simplistic terms, these are the organisations that can translate basic knowledge from universities into more strategic and applied knowledge for the use of industry.

Figure 3.5: Intermediary type- Translator



3.4 Functions of intermediaries

In this section I will propose five functions for assessing the advantages and disadvantages of intermediaries for knowledge exchange between university and industry. These functions are derived from the channels of university-industry interaction, which were discussed in the previous chapter.

The use of functions within the innovation systems literature is certainly not new, although it is rather different to the use of functions in this dissertation. Referring to innovation systems, Johnson (2001) describes a function as “the contribution of a component or set of components to the goal”. Many of the studies within the innovation systems literature refer to functions of innovation systems. Within this dissertation, however, I will refer to the functions of intermediaries, a sub-component of innovation systems. Before moving on to describe in more detail what these functions are, it is useful to mention the studies on functions of innovation systems.

Hekkert et al. (2007) describe the functions of innovation systems as the activities that contribute to the goals of an innovation system, which they argue are the generation and diffusion of innovations (p.415). Their main goal with using a functions approach is to analyse the activities that result in technical change, arguing that most analyses in the innovation systems approach are static in nature and the explanatory power lies more in the institutions than in the entrepreneurs. Shohet and Prevezer (1996) have a narrower focus and they make a functional classification of institutional actors in technology transfer, of which intermediaries are one of the actors. Both pieces of work refer to similar functions that are presented in this conceptual framework but their focus is much larger than the one of this dissertation, which is limited to intermediaries.

While in the last decade there have been several studies that have used and 'measured' functions of innovation systems; these have been mainly restricted to the technological innovation systems.

Using a similar logic to Johnson (2001) and Hekkert et al. (2007), I will use the concept of functions of intermediaries to describe activities that contribute to the goal of knowledge exchange between university and industry within this dissertation. As has been discussed in the previous chapter and also seen through the different roles of intermediaries discussed in section 3.1, there are various mechanisms for knowledge exchange between university and industry. It can be argued that the presence of intermediary organisations in any of these mechanisms would indicate that the particular channel needs facilitation. Once these channels are identified, one can assess to what extent specific intermediary organisations fulfil their function within the channel.

I have grouped university-industry interaction mechanisms into five main categories, which then correspond to the five functions that intermediaries can fulfil as shown in table 3.1.

Table 3.1: Five functions of intermediary organisations

Industry activities	***University activities***	***Functions of intermediary organisations***
Recruitment for work Access to skilled graduates Trainees Internal training Secondments	Recruitment for work Trainee placement Secondments	Provide easier access to *human resources*
Contract research Consultancy Long-term R&D projects Patents/ publications	Contract research Consultancy Long-term R&D projects Patents/publications	Provide easier access to *knowledge base*
Patents /licenses	Spin-offs/start-ups Patents /licenses	Provide increased opportunities for *commercialisation*
Laboratories Equipment	Sample materials	Provide access to *facilities and other infrastructure*
Conferences / seminars Industry clubs	Conferences / seminars Industry clubs	Provide increased access to *networks*

Source: author's own classification

The first function is 'access to knowledge base'. It has been acknowledged in this dissertation along with other academic literature that knowledge is broader than information and has important tacit components. Its movement across different components of the systems, between university and industry in this case, can happen in a variety of ways. It is for this reason that there are five functions instead of one function related to knowledge only. However, the 'access to knowledge base' function includes activities that are not covered under other functions. Some of the mechanisms included under the scope of this function are consultancies, contract research, longer-term R&D collaborations, publications and patents. In the empirical chapters, we will consider what are the advantages and disadvantages of the presence of intermediary organisations for this function, and how industry and university benefit from them – if indeed they do so.

The second function is access to human resources, which includes activities such as secondments, internships, recruitment, training and similar. Previous sections have shown that research and technology organisations (RTOs) can sometimes have a role in training students. Furthermore, the literature on science parks has also indicated that there may be increased opportunities for graduate recruitment through these organisations.

The third function is access to networks, which refers to the role of linking up previously unconnected actors. It was shown in the previous sections that this was the role that was attached to industry liaison offices directly. In an indirect manner, there is a linking up role through the presence of science parks, based on geographical proximity.

The fourth function is access to infrastructure and services. Although it includes the term infrastructure, the function excludes infrastructural services that are not directly related to research, such as building rentals, accountancy services and so on. This function addresses the service type of work conducted by companies.

Finally, 'opportunities for commercialisation' refer to activities such as patenting and licensing.

3.5 Chapter summary

As has been discussed in the first chapter, there is the problem of a 'European Paradox' perceived by several policy makers, according to which there is a need to 'bridge the gap' between university and industry. One of the bridging mechanisms that might be used to address the problem of the Paradox is the use of intermediaries.

In the previous chapter, some theoretical underlying assumptions for this argument were criticised including the market failure rationale and a linear view of innovation. This chapter aims to show how this problem can be improved by suggesting a functional analysis of intermediaries in order to understand in which area of knowledge exchange between university and industry they provide advantages and disadvantages. Derived from the multiple channels of university-industry interactions, five functions are proposed; access to human resources, access to knowledge base, opportunities for commercialisation, access to infrastructure and access to networks.

Coupled with these functions, a working typology of intermediaries forms the conceptual framework of this dissertation to be used in collecting and analysing empirical research. Based on the review of the generic and specific literature on intermediaries according to the roles they can play, four types of intermediary structures were suggested: transporters, hosts, transformers and translators. Using these structures in the empirical analysis, I will try to see whether certain functions are better suited for certain intermediary types and whether there are new intermediary types not highlighted sufficiently in the literature.

The following chapter will explain the methodology used to analyse the five functions described in this chapter for the empirical case studies.

CHAPTER 4: RESEARCH METHODS

The aim of this chapter is to present the research methods employed in this dissertation and to discuss how they are used to address the main research problem through operationalising the conceptual framework. Based on a review of the literature, Chapter 2 showed that there are gaps in the literature including the lack of systemic studies on intermediary organisations (IOs) in terms of the functions they are supposed to fulfil as well as the lack of in-depth studies for different sectors. Chapter 3 has presented a simple conceptual framework that has been developed to make it possible to conduct a functional study of the intermediaries.

To remind the reader again, the main research problem in this dissertation is to *identify the advantages and disadvantages of intermediary organisations in promoting knowledge exchange between university and industry*. While this is the main research problem, the Netherlands and the UK agricultural biotechnology sectors are chosen as the cases in which the problem is studied.

Section 4.1 discusses which qualitative methodologies this dissertation draws upon. The reasons behind the choice of agricultural biotechnology and the two countries are briefly explained in section 4.2. Section 4.3 presents the practical details about the methods used in this dissertation, followed by an outline of the data analysis in section 4.4. Finally section 4.5 gives a brief summary of the methods used and their possible shortcomings.

4.1 Qualitative approaches used

While the approach used in this dissertation cannot be strictly described as one specific form of a method or another, it strongly draws upon the case-study methodology and uses elements of the 'grounded theory' methodology. This section discusses these methods and where the dissertation draws upon them or diverges from them.

The technical definition of a case study as presented by Yin is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (2003: 13). Within this dissertation, the contemporary phenomenon studied is the intermediary organisation, and I argue that sectoral and country contexts have effects on the formation and functioning of these organisations.

Yin (2003: 5) refers to three questions that should be addressed when choosing a research strategy: (a) the form of the research question, (b) the control of the investigator over the behavioural events, and (c) the degree of focus on contemporary events. The questions underlying the research problem posed in this dissertation are closer to the 'why' and 'how' forms than to 'how many' or 'how much'. The first part of the research problem consists of an exploratory phase in determining the advantages and disadvantages of intermediaries, and for this part a survey or questionnaire could be equally well suited. Nevertheless, such a strategy would not provide the in-depth study that is necessary for exploring and explaining the reasons behind why and how certain intermediary organisations can provide these (dis)advantages. The explanatory part of the research is also necessary for two reasons; firstly, to trace the changes in the country policies and as well the changes in the structure of the industry and how they effect the current organisational forms and practices; and, secondly to provide more elaborate and specific policy recommendations for the industry that is studied. As for the second and third questions posed by Yin, there is no control over the behavioural events within this research; and although history is taken into account, the focus is mainly on contemporary events. Given the answers to these three questions, the case study approach would seem to be an appropriate methodology to be pursued in this dissertation.

An important step within the case study methodology is defining the units of analysis. With regards to the units of analysis, Yin (2003) introduces four types of case studies: single case holistic, single case embedded, multiple case holistic and multiple case embedded. While the holistic cases have a singular unit of analysis, embedded ones have more than one. Taking into account that this dissertation is a cross-country comparison, it is obvious that it falls within one of the two multiple case designs. The challenge is defining whether it is a holistic or embedded case study (see figures 4.1a and 4.1b respectively).

The comparison of the same sectors in the two countries is most similar to a holistic multiple-case study. Hakim (2000) also writes that "the holistic case-oriented approach treats each country, person or other social unit as an integrated, complex whole, and is sensitive to complexity and historical specificity" (p.13). However, the study of agricultural biotechnology sectors is further divided into (1) companies (SMEs and MNEs) (2) PROs and (3) intermediary organisations. If these are taken to be the units of analyses, then the structure is more similar to an embedded multiple case.

Figure 4.1a
Holistic multiple case

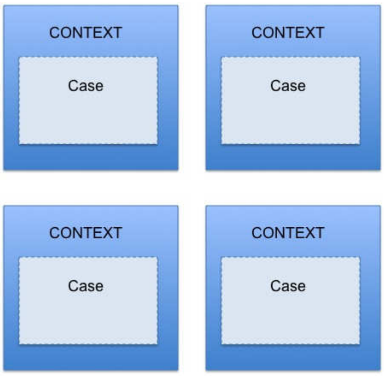
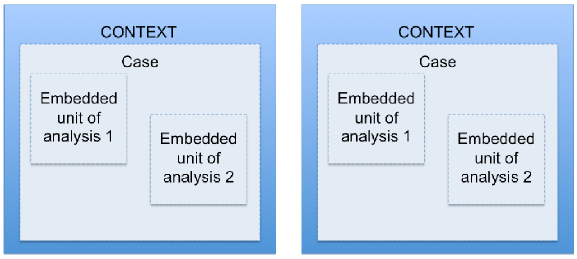


Figure 4.1b
Embedded multiple case



Source: Yin, R.K. (2003: 40)

In this dissertation I take agricultural biotechnology as a whole unit of analysis rather than treating different organisations as separate units. Although each firm has been interviewed, the focus is not on individual histories of the firms, but rather on the sector itself.

The diversion from the case-study methodology comes at the point of developing prior theoretical propositions to be used in the research and analysis. The previous chapters indicate certain weaknesses in the literature and therefore suggest certain factors that should be taken into consideration, but these are more guidelines than propositions. The analysis in this dissertation is mainly carried out in the light of these guidelines, but is not limited to them, and is further extended by looking out for emerging concepts as in the grounded theory methodology.

Eisenhardt (1989) looks specifically into building theories from case study research through a synthesis of the previous work on qualitative methods, case study research and grounded theory building (p.532). In this process, the third step that follows the definition of research question and a priori constructs is a step that she describes as "neither theory nor hypothesis". She writes, "preordained theoretical perspectives or propositions may bias and limit the findings" (p.536). This is the step that has been mentioned in the above paragraph in terms of departure from the traditional case-study research design mentioned above.

While this dissertation does not follow a grounded theory approach completely and does not aim to build a theory as a conclusion, it does benefit from the approach in terms of analysis. It is also similar to the approach in terms of comparative analysis being an important strategy in generating theory (Glaser and Strauss, 1967) through highlighting distinctive elements of the study or through verifying initial ideas or theory.

4.2 Choice of agricultural biotechnology and the two countries as case studies

While it has been partially described in other parts of the dissertation, in this section I will briefly describe the reasons behind the choice of the agricultural biotechnology sector as well the choice of the NL and the UK, and explain why they are comparable. Further reasons behind these choices are explained in Chapters 5 and 6.

Biotechnology in general has been in the spotlight of studies regarding university-industry relations for more than two decades (Kenney, 1986; Powell, 1996; Zucker et al., 2001). The main reason for this is the knowledge-dependent character of biotechnology and the resulting frequent interactions between university and industry. Furthermore, as mentioned in previous chapters, the rise of intermediary organisations coincides with the rise of the biotechnology sector. Therefore, the choice of biotechnology in general will almost certainly guarantee that university-industry interactions will be observed and intermediary organisations will be involved to some extent in this process. However, it is not possible within the scope of this dissertation to conduct a meaningful in-depth study of the whole biotechnology sector. This is firstly because of the complexity of different elements involved and secondly because of the practical limits of the methods used.

In addition to the practical issues mentioned in the above paragraph, there were other considerations in mind while choosing a sector of study. Chapters 2 and 3 discussed how the studies were mainly limited to a few lucrative areas such as pharmaceutical biotechnology while other fields were understudied, which creates the risk of drawing conclusions from a very limited and special field with regard to general policy applications. By studying a sector such as agricultural biotechnology, this dissertation provides information on a less well-known field and may prompt further studies of seemingly high-tech sectors, which in reality function rather differently from the few lucrative ones.

While the dissertation concentrates on the study of intermediary organisations in the agricultural biotechnology context, the analysis is broadened to include an examination of science and technology policies in the Netherlands and UK in relation to their effect on the formation and functioning of intermediary organisations in the two countries. Previous studies include the comparison of the biotechnology sectors in these two countries (Senker, 1998; Enzing et al., 2004) as well as comparisons of different parts of the science and technology policies and institutions (Brickman and Rip, 1979; OECD 1990: Kuhlmann, 1991). However, these studies are looking more at the macro level and may not reveal differences and subtleties underlying the biotechnology field, for example, that need more focused and detailed studies.

The comparison of the Netherlands and UK has been mainly based on the interest on the difference between the popularity and reasons for the existence of intermediary organisations within the countries. As will be explained further in the following chapters, UK has been one of the early movers in Europe to encourage its universities to engage in technology transfer activities and to establish organisations for the facilitation and management of these activities. The Netherlands, on the other hand, has been relatively slow in these activities until recently. As mentioned in the previous paragraphs, biotechnology is a sector that is well suited for the study of intermediary organisations. Previous reports on European biotechnology systems (Reiss et al. 2003; Enzing et al. 2007) have classified the Netherlands and the UK within the same class in terms of creation of a knowledge base and commercialisation of biotechnology. While medical biotechnology is a possible industry for comparison in the two countries, much has been written about this field and although focusing on the same field can yield theoretical contributions, it is less likely to bring out contrasting results. On the other hand, university-industry relations in agricultural biotechnology is a much less researched area and has the potential to yield more novel results.

4.2.1 Defining the agricultural biotechnology sector

Before going into the analysis of the case studies in the following chapters it is useful to introduce the sector briefly in terms of its nature and characteristics and how it is limited within this dissertation. In chapter 6, the nature of the defined sector will be further discussed in the light of concepts borrowed from the technological regimes literature. I will briefly discuss the definition of the biotechnology sector, what are the different applications to it, what the agricultural biotechnology covers in general and particularly in this dissertation.

The single definition of biotechnology as described by OECD is "The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services"[14]. Authors also make distinctions between first, second and third generation biotechnology where the third generation is marked by the recombinant DNA technology which allows intervention at the gene level by combining or inserting DNA strands into organisms. With such a broad definition of biotechnology comes the difficulty of classifying biotechnology. Brink et al. (2004) present two axes along which classifications can be made: the knowledge base and the product base (p.24), however they associate more problems with using the former. According to the product base they suggest eight areas[15], of which one is agriculture.

The use of biotechnology in agriculture goes back a long time with cross-breeding methods but the introduction of biotechnology has enhanced crop improvement in a number of ways which is described more in depth in chapter 6. Describing the agricultural biotechnology industry also presents to be a challenging task with blurry boundaries. Looking at the product base and what is commonly referred to

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[14]http://www.oecd.org/document/42/0,3746,en_2649_34537_1933994_1_1_1_1,00.html

[15] These are: medical biotechnology, pharmaceuticals, food, instruments and equipment, environment, forestry, pulp and paper, chemistry and agriculture (Brink et al, 2004, p.28).

under 'agricultural biotechnology, one can see three main sectors: food, animals and plants. Within this dissertation, the use of 'agricultural biotechnology' refers to application in plants and does not include the food or animal sector. While another option would be to use the term 'plant biotechnology' to be more specific I have chosen to use 'agricultural biotechnology' along the nomenclature of previous projects and works by authors like Bijman (2001). In Chapter 6 it will be explained in more detail that because of sector independencies, agricultural biotechnology collectively will refer to agrochemical companies, seed companies and new biotechnology firms. The application of agricultural biotechnology to animals is not included in this dissertation.

4.3 Use of the methods throughout the dissertation

As described previously, the dissertation mainly draws upon the case-study methodology as well using elements from the grounded theory approach. In this section, the details of the application of these methods are explained.

Chapters 6 and 7 construct the context of the case studies in terms of the countries and the sector studied, similar to what Eisenhardt (1989) describes as case study write-ups that are "central to the generation of insight" (p.540). They provide a historical account of the innovation systems and the industrial sector in these two countries, in particular how their evolution affected the formation and functioning of university-industry relations and intermediary organisations. This meant identifying the institutional and knowledge characteristics of the countries and sectors respectively that have influenced the development of intermediary organisations.

The information used in these chapters comes from both primary and secondary sources. For Chapter 6, the main resources have been secondary sources that include reports from industrial associations, consultancies and sectoral magazines. In Chapter 7 primary sources have been used whenever possible. In the case of the Netherlands, while government documents from the last decade or so are available in English, accounts of other authors have been used for earlier years. In the case of UK, mainly primary sources have been used as well as some secondary sources. For both countries, primary documents include governmental reports consisting of ministerial reports, departmental reports and strategy papers.

The data regarding the two countries have been organised with the national systems of innovation framework in mind, offering two advantages. Firstly, it makes the connection between Chapter 2 and 7 clearer by translating the concepts discussed in the former to country-specific information in the latter. Secondly, a systemic review and analysis of country information makes it easier to show the effects of history on the differences between the formation and functioning of intermediary organisations.

4.3.1 Interviewee selection

As both Eisenhardt (1989: 537) and Yin (2003) explain, a case-study approach relies on theoretical sampling instead of statistical sampling. The selection can be made for the purpose of replicating or extending previous theory, to "fill in theoretical categories and provide examples of polar types" (Eisenhardt, 1989:537). The choices are influenced by the conceptual questions rather than a concern for representativeness (Miles and Huberman, 1994: 29). The choice of interviewees in this dissertation relies more on these principles and the selection process is explained in the following paragraphs.

The most difficult part of the interviewee selection was with the firm selection. Considering that the research problem is concerned with knowledge exchange between university and industry, the challenges of firm selection have been two-fold. The first problem is ensuring that firms lie within certain sectoral boundaries[16], while the second is determining the firms that are engaged in knowledge-based activities. With these considerations in mind, multiple steps were taken for the firm selection.

The initial step was the formation of a raw preliminary list of firms working broadly in the agricultural biotechnology sector through the utilisation of a number of resources. The resources that were used and their descriptions are given in appendix 1.

Following the formation of the starting list, each firm's website was scanned with the above two considerations in mind. This meant the exclusion of firms that are

[16] This means being involved in either seeds, crop protection or the agricultural biotechnology field.

only distributors or that deal with more peripheral areas such as machinery, glasshouses and similar topics. Furthermore, firm websites were searched for 'research' as a keyword – this providing a sign of involvement in knowledge-based activities - and firms without this keyword have been excluded[17].

While the keyword search has been a useful way to identify relevant firms in most cases, the presence of the word 'research' does not guarantee the activity itself takes place, as there are numerous firms that do not differentiate between research and/or development activities. In order to make sure that the selected companies are engaged in research, additional indicators were examined. These include patents, grants, and involvement in national and/or international research projects. The details for the methods used in searching for these indicators are also explained in appendix 1. In addition to the above firms, MNEs were included in the list even if they do not conduct research in the Netherlands and/or UK because of their important role in the sector.

In the case of industry, the individual interviewees were identified through company websites or web searches whenever possible in order to find the right people managing R&D in the company. Targeting a relevant person has also increased the chance of receiving positive answers to interview requests. By choosing R&D managers/technical directors as the interviewees, the possibility of getting an overview about research cooperations at the firm level is increased and a chance to learn about the history of these cooperations arises as well. Given that the company sizes in the sector are not very large - except for a few MNEs - it can be assumed that the research directors will generally have a reasonably reliable overview.

In the case of universities, either groups working in agricultural biotechnology were identified first, followed by finding the relevant interviewees, or individual academics were identified through their involvement in research projects, patents, and so on. In the case of identifying individuals through departmental web pages, further searches on academics were carried out on their personal pages or the web

[17] If firms have been identified to be involved in knowledge-based activities through other indicators such as patents, projects, collaborative grants and the like, they have been included in the sample regardless of what their webpage says.

to look for signs of industrial cooperation or funding in the past or present. The researchers targeted were mainly senior academics for two reasons; to explain the changes in the cooperation and technology transfer strategies over time; and to explain changes in the field of agricultural biotechnology. Furthermore, some of the senior researchers have also worked in industry in the past and were able to provide insights into the differences between university and industry. Finally, in the case of intermediary organisations, it was the head of the university technology transfer offices that was approached.

4.3.2 Interview guideline and process

The interview guide, which can be found in appendix 2, was designed to reflect the five functions described in the previous chapter. After an introduction of the study and a description of what intermediary organisations are, the interviewees were asked whether they have collaborated with another organisation within the last three years. The time frame was introduced with the aim of having a standard across the interviews, but in many cases collaborations with longer time frames were taken into account as well, which made it possible to reflect on changes that might have happened regarding collaborations.

The initial questions have been left more open-ended mainly in order to build an easier rapport and listen to what each interviewee has to say regarding collaborations in general. They were asked to describe the nature of the collaboration in order to figure out whether the type of collaborations or the choice of collaborator was related to specific types of knowledge. Interviewees were asked about the aims behind the cooperation in order to understand whether there was a match between the university and industry's aims. The short and long-term benefits were also discussed to provide a similar comparison. The initiators of the collaborations were questioned to see whether these collaborations were built directly or an intermediary organisation was involved in establishing the collaboration.

The interview guideline also included questions about the type of organisations the interviewees collaborate with in order to understand whether certain organisations serve specific functions. The final part of the interview asked about each of the five functions specifically to understand how each of these are covered by the interviewees, regardless of whether or not they have collaborated with other organisations for these functions. The interview guideline also provided the possibility to prompt for the reasons as to why some interviewees had no collaborations.

The interviews were conducted partially face-to-face and partially over the phone depending on the location of the interviewees. Prior to each interview, a web search was conducted to identify any collaborations that the interviewee might have had, which were then used to remind the interviewees of past collaborations whenever necessary. Each interview was recorded on tape after getting the consent of the interviewees, who were guaranteed confidentiality of information and anonymity in the text. All the interviews were transcribed.

4.4 Analysis of the data

The first part of the data analysis consisted of analysing the interviews through the five functions described in the previous chapter to gain an initial understanding of whether intermediary organisations presented certain advantages or disadvantages for these functions. It emerged through this initial analysis that these advantages or disadvantages were dependent on certain sector and country characteristics. These characteristics were then analysed in the following chapters, where primary data from the interviews was combined with secondary data. Finally, the synthesis chapter attempts to bring these multiple characteristics together to see what sort of sectoral characteristics and national institutions affect the way that intermediary organisations form and behave.

As mentioned in the previous sections, the research methods used in this dissertation draw upon the notions employed in both the case study and grounded theory approaches. The categories derived from the conceptual framework are used as a basis for the analysis of the data as in the case-study methodology. Nevertheless, they do not limit further analysis from searching for and deriving new categories and properties, which is one of the essential steps in the grounded theory approach.

4.5 Summary and challenges of the research methods

In this chapter, the research methods used in this dissertation have been explained. While the case-study approach is the main methodology that has influenced the design and execution of the research, the empirical chapters have further benefited from the grounded theory approach. Chapters 6 and 7 provide an explanatory context for the cases as well as generating new insights by showing how sectoral and country-specific contexts can affect the intermediary organisations. Chapter 5 is the exploratory part of the dissertation, presenting the primary data obtained through the operationalisation of the conceptual framework through interviews.

One of the concerns expressed about the case-study approach is the problem with generalising. The aim of this dissertation is not to provide a generalisation on all of the intermediary organisations working in different sectors or countries. However, it does provide an insight about the agricultural biotechnology sector, while signalling that there might be other sectors with similar problems or variations upon them.

While I attempted to carry out interviews in a way that they could be triangulated with each other, this was not always possible. Some of the companies refused to give interviews, while in other cases the interviewees could not recall specific incidents or the people involved in the collaborations have since changed jobs.

A further possible concern with the data is the lack of interviews with academics that have not cooperated with industry at all. However, interviews with academics did point to problems that may compensate for this gap.

CHAPTER 5 – EMPIRICAL FINDINGS

In this chapter I will present and discuss my empirical findings along the lines of the five functions that have been presented in Chapter 3 and which also formed the guideline for the interviews. The five functions are: access to the knowledge base, access to human resources, access to networks, access to facilities and other infrastructure, and opportunities for commercialisation. These functions were used to discuss the main research problem of this dissertation, which is to determine the advantages and disadvantages of intermediary organisations (IOs) in facilitating knowledge exchange between university and industry, and what are their specific advantages and disadvantages with regard to this relation. In Chapter 3 a conceptual framework was presented, which was constructed by characterising university-industry relations in terms of five functions. As explained in the previous chapter, these functions then provided a framework for the interviews conducted. The next sections in this chapter will present the results of these interviews on whether IOs play a visible role with regard to a particular function and if so how. These results are then compared with the rationale behind the policies that promote intermediary organisations as a possible solution to problems relating to knowledge exchange and technology transfer.

As this chapter will show, the analysis of functions and whether IOs perform a significant role is closely related to the sector and country that is being studied. Chapters 6 and 7 will look at the sector and country specificities respectively and will present the rest of the empirical findings, along with other secondary data, which will complement this chapter. As such, this chapter will not go into the particularities of the sector nor the institutional context in the two countries.

The following five sections each look into the respective functions, first determining whether there are relations between university and industry that relate to that function, and then discussing whether there is an appreciable role for IOs or not. The final section contains a summary and links these findings back to the relevant academic literature.

As the analysis will show, there are no clear-cut boundaries between the five functions. For example, while accessing human resources might be the direct action, the underlying aim can be to extend networks and also to access knowledge at the same time.

5.1 Access to the knowledge base

It was shown in Chapter 2 that there are a variety of channels through which university-industry relations take place and many of these channels provide the interacting parties with knowledge. It is therefore difficult to precisely define and separate the 'access to knowledge' function from some of the other functions. To give a concrete example, studentships are categorised under the 'access to human resources' function but this inherently includes a knowledge element. While it is difficult to define and isolate this function, what is done here is to leave out the channels already covered under other functions and to take into account more specific forms such as joint R&D, collaborative research, consultancy work and similar activities.

Almost all industry interviewees have been engaged in collaborative activity with universities, and vice versa for universities. It is important to understand why companies engage in these types of relationship and what kind of knowledge they seek from universities. Should there be a role for an intermediary organisation, it should be to facilitate the exchange of knowledge sought by university and industry. Furthermore, as demonstrated in Chapter 2, the type of knowledge that companies seek is dependent on a number of additional factors such as the sector that the company operates in, and the size of the company.

Among the companies interviewed, there was consensus about what type of research universities are good at, and in turn about what the companies look for, which was knowledge from fundamental and strategic research[18]. As indicated by several interviewees, most companies do not have the capability or resources to conduct fundamental research. Even in the case of MNEs, which have more advanced in-house R&D capabilities and which can extend their research range

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[18] Referring to Irvine and Martin (1984), Calvert (2002) describes strategic research as long-term research that is more directed than 'pure or curiosity oriented research" (Calvert 2002: 25). The author also refers to the similarity existing between the concept of strategic research and Pasteur's Quadrant, a class of research defined by Stokes (1997). Pasteur's Quadrant is defined by research where there are practical problems to be solved by researchers but these problems are approached through fundamental methods.

towards the more fundamental end of the spectrum, there is a strategic goal for building a knowledge base that can support their own innovative activities rather than conducting ‘blue skies’ research that is mainly driven by intellectual curiosity.

Smaller firms are less able to conduct basic research for various reasons and therefore there may be opportunities for consultant type organisations to provide them with a background knowledge, which the smaller firms can then use to develop new products. While this was not a role voiced often during the fieldwork, a consultant interviewed in the Netherlands explained the issue as such:

> “They wanted to start new projects make new products, but they didn’t know a lot about the products, they didn’t know about the technology so they hired me to make proposal or judge other proposals as well and doing IP research and things like that...they wanted to make a product and then they didn’t really know what the main characteristics would be for a product, what product would be best, how to produce them with what type of companies they could collaborate...Is there a room for making another product, how you can do it, with what kind technology you could do it with and things like that. So its combination of university knowledge and knowledge about how companies work and what is important in getting a product to the market.” (consultancy, NL)

While the literature also confirms that many small firms do not conduct basic research, with the exception of dedicated biotech firms, it is also shown that firms do invest in basic research for several reasons such as increasing their absorptive capacity, increasing the capability to make effective decisions about the outcome of their applied research, gaining first-mover advantages and so on (Rosenberg 1990). Therefore, when the interviewees reported that they do not conduct fundamental research, it is likely that they meant ‘blue skies’ research and some of them do actually conduct more basic research than the others. While it is not possible to clearly determine whether firms do conduct basic research or not, none of the industry interviewees stated that they are interested in conducting applied research or development with universities, supporting their claim about being interested in getting more strategic research from universities. Studies on biotechnology sector also confirm that large firms conduct their development work in-house and rely on universities for basic research (Arora and Gambardella 1990: 364).

Elements of risk and the high costs associated with fundamental research seem to be the main reasons as to why companies prefer to leave this type of research to universities:

> "In-house we tend to concentrate on applied science and if we've got an idea that is very fundamental, we often say, "let's have the university test it out for us". It's a cheap way of doing fundamental research. If it fails, well it's not one of our core projects. If it succeeds, than we can build on it and then apply it." (industry, UK)

For universities, several academic interviewees have mentioned that their gains from industry in terms of knowledge is in the form of ideas for future research areas and applied techniques, differing from the type of knowledge that industry gains from university. A certain irony can be seen in this in the sense that 'technology' transfer tools aim to direct technology - and techniques - from university to industry and not the other way around. This is yet another example of how there is a natural division of labour between university and industry, with industry having more expertise in applied techniques and technologies.

Some industry representatives also voiced their concern regarding the push of universities towards commercial objectives considering basic research – which may have less visible benefits – is actually what the industry is interested in getting from universities. A similar result is presented in the study of Glenna et al. (2007) who interviewed industry members in the US. Nevertheless, it is difficult to judge the objectivity of such comments as industry members may also be complaining about having to pay more for research in the last decades with the increasing interest of universities on IP as well as cost-recovery operations such as full-economic costing.

5.2 Access to human resources

Company interviewees were asked whether they interact with universities through channels including human mobility, for example by funding studentships, or hosting internships or secondments. The majority of the interviewees reported that they have been involved in such interactions.

One of the most common forms of this type of relations that was mentioned during the interviews was the funding of studentships. Almost all industry interviewees regarded this positively for a number of reasons. Studentships were said to provide a chance for conducting research in a cheaper and controlled[19] manner and they also serve as a means for companies to keep in touch with current research. The reasons as to why firms engage in this type of relationships are similar to those mentioned in the previous section:

> "So, where we use a studentship is where there's a narrow interest which we're not sure it's an interest or not, or a piece of technology which we'd like to know more about but we don't know whether we're going to be using or not, but it's into that space where we don't really know yet, and this is an efficient way of finding it out." (industry, UK)

In the UK, studentships are particularly favoured by companies because, through government-sponsored programmes such as LINK and CASE, companies pay only part of the studentship, creating a cheap option for funding research. In the Netherlands, none of the interviewees mentioned such a government programme although companies do fund studentships directly. However, as will be mentioned in the following chapters, in the Netherlands studentships are also provided within the large collaborative programmes between university and industry.

Another reason as to why companies fund students or host interns is to secure future employment at a period where there are less taught programmes and a decrease of student interest in the field of plant sciences.

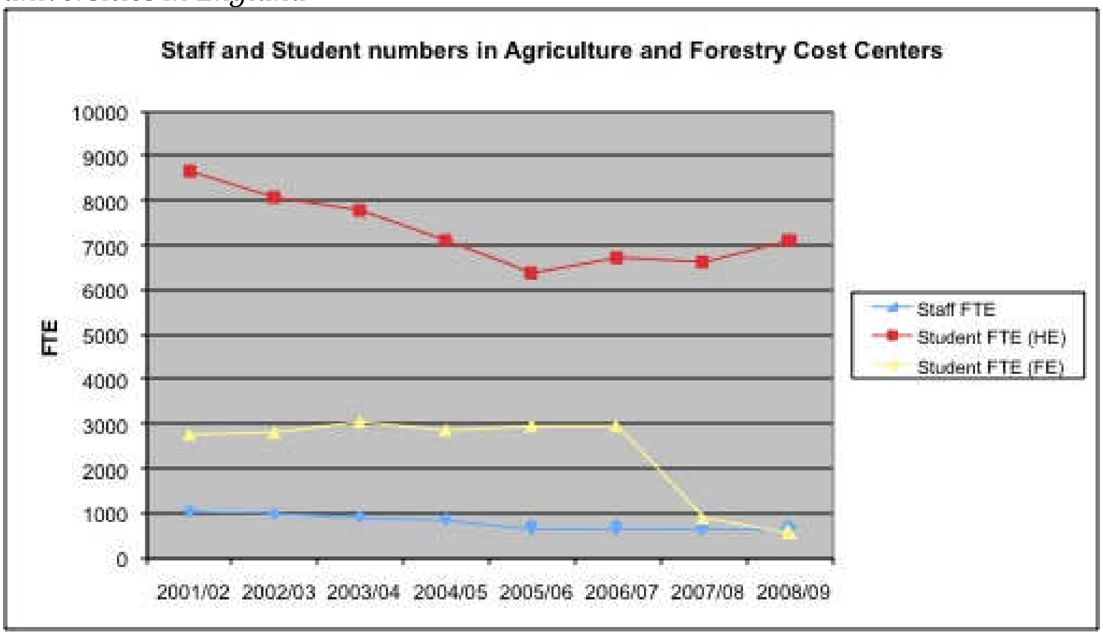
> "We have looked at that, for example providing partial student sponsoring because these people are quite hard to find when you want to recruit them, so we need to find a way of encouraging people to come to us when they finish their degrees, and it also keeps you up to date with what goes on in that group." (industry, UK)

[19] 'Controlled' in this context is used in contrast to departmental collaborations where more academics are involved in the project than just the student and the supervisor.

> "If you don't do an internship, you can't graduate, that's the most important thing because for us it's very difficult for us to find the right type of experience at this time. Plant biology is not a very hot topic…Often we hire people who worked as interns in [the company]" (industry, NL)

In the case of England, data from the Higher Education Statistics Agency (HESA) on the number of full-time equivalent (FTE) students in the agriculture and forestry field show that there is indeed a decline in the number of students in further and higher education (figure 5.1). Nevertheless, it is not possible to use these data directly as supporting or opposing the claims made by the interviewees since the cost centre includes forestry and it is likely that many of these students work in farms rather than in companies working in the field of agricultural biotechnology-related industries.

Figure 5.1: Staff and student numbers in agriculture and forestry costs centres of the universities in England



Source: constructed by the author based on HESA data

The OECD statistics on the number of FTE R&D personnel in agriculture, hunting and forestry as a percentage of total R&D personnel in business enterprise show that in the Netherlands there has been a 10% decrease between 1998 and 2007, although most of this period has seen a decline with a sharp rise from 2005 onwards. On the other hand in the UK, the percentage of R&D personnel in this field has been steadily declining from 1.3% in 2001 to 0.7% in 2007, showing almost a 50% drop, this can be considered to support the claims about the shrinking of the plant breeding sector in the UK.

The report prepared by BioHybrid International and ADAS Consulting (2002) also alludes to the problem that there are very few agricultural courses left available in the UK and most courses are to be found in botany or genetics rather agriculture. The closure of many public sector research institutes, which also trained breeders, has also contributed to this problem (p.41).

Studentships are also considered as a way to sustain or extend networks for both the research base and industry, providing yet another channel of networking through informal relations rather than more formal ones: "A lot of our alumni go into industry and we have interactions through them that way." (PRO, UK). Especially in the case of the Netherlands, it was mentioned by many interviewees that they have done a course at Wageningen University[20].

In terms of secondment and staff mobility practices, a significant country difference was observed from the interviews. In the Netherlands there seems to be more flexibility for a bi-directional flow between universities and industry. Academics can act as consultants for companies through a buy-out of their time from the university by the firm. In the other direction, industry members can become "0 professors" in universities, where they can give lectures and engage in other activities without being paid.

While secondments or mobility have not been brought up as an issue during the interviewees in the UK, this might be due to a sectoral bias and does not mean it does not exist. Mobility schemes for academics can be found in other disciplines such as the Industrial Secondment Scheme initiated by the Royal Academy of Engineering or the Research Assistant Industrial Secondment scheme by the

[20] Wageningen University and Research Centre (Wageningen UR) is an agricultural research complex in the Netherlands, consisting of the Wageningen University, the Van Hall-Larenstein University of Applied Sciences and the former agricultural research institutes (DLOs) of the Dutch Ministry of Agriculture (LNV). Wageningen University has been the sole dedicated agricultural university in the Netherlands, getting funded by the LNV. Further relevant information about Wageningen UR will be given in the relevant context in coming chapters.

Engineering and Physical Sciences Research Council (EPSRC). Nevertheless, outside engineering it is difficult to find explicit, centrally funded secondment schemes, and furthermore a report for HEFCE looking at the effectiveness of third stream activities in the UK indicates that personal secondments to external organisations are very infrequent among a variety of knowledge exchange activities (PACEC & CBR 2009: 132). It has also been noted that the nature of the Research Assessment Exercise in the UK may hinder academic secondments to business by reducing the quality and quantity of research products (HM Treasury 2002: 55)

In terms of accessing human resources, intermediary organisations seem to play a role in a very specific area: hiring senior level researchers or managers. Studentships, internships and secondments take place through personal networks and advertisements in the media. However, interviewees from industry in both countries expressed the view that they have used or may use a specialised human resources agency in finding senior people for research, such as R&D directors. Only one of the interviewees complained that the agency did not bring in anyone they did not already know.

> "We use HR agencies quite often especially when you're looking for more experienced people on a senior level… At the senior level, it's very difficult to attract those people with ads…" (industry, NL)

> "The lower levels we'd normally advertise locally, through intranet or internet, and just occasionally we might go to a specialist journal like New Scientist…not very often we do. Because of the nature of the science we don't normally do that. If we're going for the more senior positions, we'd also do those ads but we might get a head-hunter out there" (industry, UK)

> "We use HR agencies quite often because especially when you're looking for more experience people on a senior level... if you're looking for really experienced senior people who have a certain background, I'm very happy with the help of certain agencies in Holland. They do good work, have a good network, they understand what you're asking for and come with limited number of good candidates." (industry , NL)

While finding employees is not a particular problem for companies, there is a concern voiced particularly by industry interviewees about the supposed decrease in the supply of qualified graduates interested in plant sciences. This should have particular relevance to policy in terms of deciding the allocation of resources.

Access to human resources-summary

The interviews have shown that student and staff mobility is an important resource for both university and industry in terms of accessing knowledge, securing employment and extending networks. While intermediary organisations play a small role in finding senior-level employees for companies, they do not appear to play a significant role for university-industry human mobility. On the other hand, company traditions in accommodating interns, flexible regulations for employees in both university and industry and government-funded programme are among the factors that seem to facilitate this mobility. As will be later discussed in this chapter, the latter mechanisms are a part of what can be called intermediary institutions.

5.3 Access to networks

Networks serve as an important source of knowledge exchange not only formally but also informally. Furthermore, they indirectly affect the chances of knowledge exchange by providing direct and indirect access to funding sources for both university and industry. European Commission programme have dedicated funding streams for networking which can be considered as an acknowledgement of the importance of networks within policy circles. Organisations such as Industry Liaison Offices in the UK or Transferpunten in the Netherlands were established with one of their aims being to act as a contact point for industry to find the right people in universities for industry.

In order to understand whether intermediary organisations (IOs) play a role in the networking function, it is useful to look at why universities and industry get involved in network relations and how these relations take place. It has been shown throughout this dissertation that one of the main reasons why industry engages in relations with universities is to access knowledge. In accessing knowledge, industry can use their existing network, and if the knowledge they seek is not available in the existing network, they may look out for new sources.

Part of the networking for both university and industry occurs naturally. Interviewees from both university and industry mentioned rather conventional methods such as attending conferences and seminars, participating in projects, and being a member of industrial organisations and the like:

> "Quite important I think is contacts that start usually at conferences. When you're interested in a certain new area of application, you start collecting information, publications, names, visit conferences... Very quickly you learn who does what research and can easily approach them" (industry, NL)

> "We go to conferences so you hear, see people. You also can read articles. Internet is a good item because you can look for a certain research and find researchers and go to people". (industry, NL)

> "You tend to meet people if you go to international conferences and meetings." (industry, UK)

Institutions like CBSG where the university and industry come together on a long term basis also provide a platform of networking for academics and industry members:

> “I do have to say that we had a national program (similar to GARNET), CBSG. We are also a part of that. Most of the plant breeding companies are involved in that and via that we also know more and more people. But also one thing we have actively done at one point was we organised a meeting called strategic plant science research in Utrecht and we invited people from many companies to talk about our research.” (academic, NL)

When asked whether they use any intermediary organisations for building these regular networks, all interviewees stated that they build their contacts directly without the need of a helping organisation. The size of the agricultural biotechnology and related industries was also given as a reason for the ability to build direct contacts:

> “…because plant biotech is a fairly small business. There are only so many organisations involved and most of the contacts we make at conferences etc. rather than bumping into them because they are 100 yards away.” (industry, UK)

Although it is not a novel finding that university and industry build direct contacts, it is still important to emphasise this point as it partly contradicts the rationale behind the establishment of some IOs such as science parks and Industry Liaison Offices (ILOs). It was mentioned in section 3.2.2 that the ILOs were founded with the original mission of acting as a gateway for industry to contact academics. The interviews conducted for this dissertation indicate that there is little need for such an organisation, but it has to be remembered that this may be related to the characteristics of the sector, which is discussed in the following paragraphs.

In the case of science parks, there is an assumption that through physical proximity, the flow of information would be eased and collaborative networks would be created among tenants, as mentioned in section 3.2.3. However, such a role was not acknowledged by any of the interviewees, including a science park representative: “If the relation is purely content-based, long-term R&D-based, we don't interfere and scientists don't need us" (science park, UK).

Furthermore, the interviewees pointed out that intellectual proximity[21] is more important than geographical proximity and within the agricultural biotechnology sector this is much easier to achieve due to the density of the networks. The literature on the role of geographical proximity does not present a definitive answer on whether such proximity is important or not, and certain sectoral differences can be observed. In a comparison of a pharmaceutical and an agro-food bioregion, Coenen et al. (2006) find that knowledge dynamics in the former are less localised than in the latter one. Their findings show that in the dedicated biopharmaceutical companies, geographical location does not constitute a prime obstacle compared with the "importance of individual scientists at world leading universities with a scientific suitable profile" (Coenen et al. 2006: 410). On the other hand, they find that in the agro-food cluster the production and commercialisation of new plant varieties tend to be localised. Drawing a parallel with the results of this study, it can be assumed that since the interviewees were research directors, their search for collaborative research was less affected by geography. If the interviewees were responsible for the commercialisation of plant varieties, a different result might have been observed. Similar to Coenen et al., Zilberman et al. (1997) argue that biotechnology industry is concentrated in a few regions, including the area around UC David, which acts as a hub for agbiotech firms.

Barham et al.'s (2002) study on university patenting in agbiotech also shows that there is less of a proximity effect in this field compared to pharmaceuticals and instead, it is observed that "spillovers seem to take place where universities happen to be located in the same state as major agribusiness companies" (p.303).

While a role for liaison offices or science parks was not observed for knowledge related relations within the core of agricultural biotechnology, the interviewees indicated that there might be a role for intermediary organisations in helping universities and public sector research organisations to secure funding from more peripheral organisations and also in helping industry in finding contacts in more

[21] By 'intellectual proximity' I refer to people working in close or related research areas.

peripheral fields as well:

> "Where we do get involved is where you've got kind of peripheral stuff. One example is we're working with [...]. They have a whole bunch of capabilities around identifying pest-control compounds etc. …That's important because for the agbiotech companies, somebody like Kew wouldn't be on their radar. Whereas Rothamsted, JIC, etc, those kinds of institutes are well on their radar; they know all the academics, they see them all the time at conferences. So the companies know what's going on in those organisations. They don't need someone like us and the academics don't need someone like us because they already know the company…. As the industry focus widens, then there is the need for intermediaries to help with that role because the academics tend to know their field and their direct contacts very well, but not wider than that. And likewise, frankly, the TTOs tend to be pretty focused as well." (external IO, UK).

> "…and at the moment we're also setting up a business development unit which actually go out into industry to try and discuss, to present [PRO]'s science to negotiate new sources of funding perhaps without non-traditional funders.. I think with our traditional funders they come directly to us. But what the contract office and the business development unit is trying to find is non-traditional funders. We used to interact with agrochemical, breeding companies but there are other companies like energy…I think that is a role that we wouldn't know; where to look like professional people who can go out and talk to a range of different possible funders where they'd be interested in the type of science that we do." (PRO, UK).

> "We use TTOs especially in areas that we are not familiar with. So for example, in the US we're trying to get access to new tech that's been developed in the medical field that we can apply to the plant field." (Industry, NL)

Access to networks summary

The results of the interviews show that within agricultural biotechnology-related industries in the UK and the Netherlands, there was not a need for intermediary organisations in bringing university and industry in contact, with the exception of opening up to more peripheral fields. While no explicit mechanisms were mentioned by the interviewees, it is possible that some of these network possibilities created by large collaborative programmes may be taken as given rather than being recognised as an explicit mechanism.

5.4 Access to facilities and other infrastructure

One of the relations between universities and industry involves the former conducting more routine services such as testing, and providing the use of facilities and equipment for industry. In the field of agricultural biotechnology, these services include field trials, chemical analyses with the purpose of regulation, and other operations that require a certain knowledge base but are at the farther end of the knowledge spectrum near application.

Before assessing whether there is a role for intermediary organisations, we first enquired in the interviews whether there was a relation between university and industry based on this function. As will be described in more detail in Chapter 7, with the reduction of the public sector research organisations that traditionally carried out such services, one might expect universities to carry out such services now. The results were interesting in that it was reported by both industry and university that, in general, universities were not suitable for these types of services. There are a number of reasons for this including efficiency, cost, issues of confidentiality and the general remit of universities not fitting with this type of activity, which I will describe briefly.

Universities are, in the first place, considered to be expensive compared to specialised organisations for carrying out such services due to costing systems such as the full economic costing (FEC), which includes not only the direct cost of the service rendered but also other expenses such as institutional overheads.

> "If I go to WUR, it's not only the researcher that has to be paid but it's also all those nice buildings and the managing people and the manager on top, so their charge per hour is much higher than what I have to pay in the private companies." (industry, NL)

The perception of universities becoming more expensive could well be true, but it is debatable whether the costing is not justifiable as it is indicated that prior to the introduction of the FEC system, universities had been at a disadvantage in terms of funding.

The second reason for industry not choosing such services at a university appears to be that universities do not have the right skills or infrastructure for conducting routine work in general. In the case of field trials for the plant breeding sector, universities do not have the land to conduct these kinds of tests. In the case of agrochemicals, universities do not have the official qualifications required for conducting regulatory work.

The academic literature on university-industry relations does not exclude these routine services provided. For example, studying the land-grant colleges Buttel et al. (1986) find that "product-testing services offered to industry" have contributed significantly to college-generated income. On the other hand, it should be remembered that the land-grant colleges were established to provide extension services as well, which include such services. In the case of the Netherlands and the UK such services are traditionally provided by public sector organisations rather than by universities.

Another reason for industry being hesitant about working with universities on more applied procedures relates to concerns about confidentiality. It was noted by some of the interviewees that due to the open culture and high turnover of university employees[22], confidentiality is more at risk compared to working with private companies.

Most important of all, despite the recent push towards the generation of third stream income, universities have a limited presence in third stream activities in that the very applied or development end of the knowledge spectrum is not of interest to the university in general as an institution[23]. This was the shared opinion of academics and industry interviewees in both countries:

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[22] The quick turnover is believed to be greater at lower academic levels (junior staff), who are more likely to conduct routine work than professors.

[23] I use the term institution here as there are certainly a few individual academics who are engaged in the very applied end of the spectrum.

> "...I'm not sure that we'd find it particularly academically interesting. We wouldn't get any high impact factors out of it[24]. The university wouldn't be interested in doing it unless the company have huge amounts of money." (university, UK)

> "They're not interested in doing this sort of work. It's not fundamental research. It doesn't expand the knowledge base in the same way they try to do". (industry, UK)

There were some cases mentioned where a university has conducted service work for industry but this seems to be the exception rather than the rule:

> "So we were actually doing a service for them which in principle we wouldn't do like that because it's not our job as a university research group, but with that grant came also the possibility to purchase larger equipment….At the end of the day we haven't had any results that we could publish, which was a bit of a drawback. But on the other hand, we have now very nice equipment." (university, NL)

While universities were not considered as a significant partner in relation to facilities and infrastructure, this may not have been the case in the past according to an interviewee, who also mentioned that institutes have better infrastructure and facilities:

> "There are some universities with reasonably applied facilities, Reading and a few others, not many, still have large agriculture departments and field facilities although not as much as it used to be. But the overall infrastructure within universities is now nothing like good as it is in a research institute, because universities are businesses and they find it very hard to commit large scale money into infrastructure funding, particularly in plant sciences and agriculture which academically are not major

[24] In the UK, recurrent research funding for universities have been allocated based on the results of the Research Assessment Exercise (RAE) between 1986 and 2011. This is to be replaced by the Research Excellence Framework in 2012. Both of these assessment exercises evaluate the quality of research undertaken at British universities based on a number of indicators. An important indicator is the published research articles of the academics, which are weighed according to the journals they are published in. In turn, the importance of journals is determined by their impact factors.

> priorities any longer. The number of undergraduates is a fraction of what it was 30 years ago. So the demand of the teaching and therefore all that whole infrastructure is slowly fading away...Institutes have the benefit of being able to support longer term facilities and archives and things like strategic germplasm connections which a university wouldn't be able to do because a university would never have that ability for long term planning and support for a facility...many universities said they don't want to be in agriculture any longer, it's too expensive in terms of land, facilities and labs and everything else... "(university, UK).

Interviews from the Netherlands suggested similar roles for the PROs there:

> "Another cooperation with the TNO is sometimes specialised analytics we cannot do ourselves. Although we have good facilities there are simply things which we don't have enough demand to keep them running ourselves." (industry, NL)

> "When I go to DLO-PPO I again have a question which is a bit closer to the field, farmer. Fields trials, etc." (industry, NL)

A number of companies interviewed that carry out such services for other companies in industry confirmed the above views: "The skills we have and very often we have better equipment than many universities, and we work with tighter deadlines than universities…They (companies) wouldn't go to universities….we're cheaper and we're better." (industry, UK)

One example of a private company that provides contract research for industry as well as universities is Keygene, which is further discussed in section 5.6.

Access to facilities and other infrastructure - summary

The interviews indicate that there is not a major role for universities in providing services within agricultural biotechnology-related industries due to reasons of costs, lack of appropriate skills, questions about confidentiality, and most importantly due to the mismatch between the nature of such work and the remit of universities. Such a relation appears to be largely absent between university and industry, as are intermediary organisations to facilitate such a relation.

Nevertheless, the literature indicates that there may have been a role for public sector research organisations in providing services for industry.

5.5 Commercial activities

One of the most discussed forms of university-industry relations in the literature and in policy circles are the commercialisation activities that universities are engaged in, such as patents and licenses. As will be discussed in detail in Chapter 7, several policy tools focus on this aspect of university-industry relations, and this is also an area where a variety of intermediary organisations such as technology transfer offices (TTOs) have been established with the aim of facilitating commercialisation. As such, this is perhaps the most interesting function to be analysed in relation to the research question of this dissertation.

A large number of interviewees from both industry and university had some sort of engagement with intermediary organisations (IOs) in relation to commercialisation activities, although these activities do not seem to be the most important channel of university-industry interactions, as mentioned previously in the section 2.2.1.

Opinions were mixed as to whether the involvement of technology transfer offices in the commercialisation process is beneficial or not. A well-functioning organisation can facilitate the process of commercialisation, as academics usually do not have the skills or interest in the legal and bureaucratic procedures involved in the process.

> "By and large, it's been pretty supportive. I think they play a valuable role. Because they have an area of expertise that sometimes us scientists may be a bit naive about. We know the research area, they know the legal frameworks…. If we want to do patents, it's essential to get the right support from the university because I couldn't do it on my own." (academic, UK)

Dalpe argues that the establishment of transporter organisations like the industrial liaison offices have helped the networked nature of biotechnology by managing contracts and intellectual property (2003). However, the following paragraphs will discuss the disadvantages of such organisations. It can be argued that a shift of transporter organisations from a supporting role to a more central one may be the cause of such disadvantages.

In addition to handling the bureaucratic aspects of commercialisation activities, TTOs seem to play a positive role in negotiating the publication rights and secrecy times for academics within a collaboration with industry:

> "It's essential. If you're negotiating with industry, you have to have a state-of-the art contract department negotiating on equal terms with them, and be able to understand what industry is trying to get out of it, and sometimes put constraints on it. The industry will try to control a lot of what you do, particularly in terms of publication and disclosure of information. We need to have a balance between their commercial sensitivity and our rights to publish. Because the outputs from us are usually high-quality publications." (PRO, UK)

While enquiring about commercialisation activities remarks on TTOs suggested that they can have adverse affects on access to knowledge as well:

> "I noticed over the years it used to be perhaps fairly amateurish, but the universities all got their IP offices in place...and suddenly we were not negotiating directly with the academics....The academic institutes saw ways of generating income, and I can remember one or two occasions it did cause problems because in the end... there were one or two instances where we wanted to fund the particular academic or we wanted to try and encourage some new people to enter the science base in the UK because there are less and less people entering agricultural sciences....But I do remember this causing problems because the unit were trying to impose quite a lot of restrictions on any IP that came out of the research, not that much would have come from a PhD student...I always remember that my legal colleagues were getting very frustrated with it , almost to the extent where we said is it really worth it?" (industry, UK)

> "I sometimes wonder whether or not the technology transfer is aimed to try and get money in or to benefit scientific research, where people almost forget that's the basic reason for doing this in the first place, which is to

> generate knowledge and if you generate knowledge you want everyone to share that knowledge so it's used" (industry, UK)

The interviews confirm the findings of previous works on TTOs in terms of the factors that affect the success of these organisations, such as flexibility, speed and general skills:

> "Bad ones are very rigid in what they want in the agreement, because every project is slightly different, and some universities seem to have a template and we have to have what's in this template, and sometimes that doesn't quite fit". (industry, UK)

> "I try not to involve them if I can. I just want to do the research. If I start to get various people involved, it starts to come down to IP and all that kind of stuff, and that just slows me down. I don't get anything positive from it at all". (academic, UK)

> "…going through a third interface, it becomes, I think, more structured and that mean also less speed and flexibility…" (academic, NL)

In addition to the above barriers, a common cause of problems between TTOs and industry seems to be the unrealistic demands of TTOs in terms of the value of the product[25]:

> "The seed industry doesn't have a big market opportunity in terms of real money. So to lock up IP and demand royalty share of anything we develop might create problems for us because there isn't a lot of royalty in the first place...the other thing is that some of the people involved in technology transfer were quite zealous and almost believed there was huge amount of value in everything that is produced by these projects and a lot of the time there isn't. It's just great scientific knowledge...I believe it in many respects because of the nature, our business area does not actually have huge financial value of the market place and we've got caught up as a small element where technology transfer managers are involved and arguably they don't actually add a lot of value." (industry, UK)

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[25] 'Product' in this context also includes patents, licenses and the like.

> "I think that is a problem for [universities] that they think "Oh, we have done a tremendous work and this is so high in value and potential. And then they say for the last 4% of effort, we need a real company who is going to sell the product. Whereas I think when they start realising that actually, of course, they have done a wonderful job but they have done only maybe 15-30% of the whole of the development chain…". (industry, NL)

However, even for more experienced TTOs with general business skills, overvaluation can be a problem because of the lack of knowledge of TTO staff in the field of agricultural biotechnology. The next chapter explains in detail that agricultural biotechnology is not a sector with high appropriability within Europe. Several interviewees complained that the TTOs treat agriculture the same as they treat pharmaceuticals - a sector that is far more lucrative:

> "In general, for example in […] they were very much used to making contracts with the pharma industry, so in that case if you have a compound that works, then you can ask quite a lot of royalties because the compound makes you medicine. But in the case of a gene you cannot sell a complete variety, you need extra added value which is put in by our breeders… It took some time before they could see our point of view. At first, they negotiated like we were a pharma company." (industry, NL)

> "If you take biology as a whole, there are some financially very lucrative areas and other which are not. And seed industry doesn't have a big market opportunity in terms of real money. So to lock up IP and demand a royalty share of anything we might develop creates problems for us because there isn't a lot of royalty in the first place". (industry, UK)

One could argue that the above views may be biased as industry does not want to pay[26]. However, problems caused by the lack of sectoral knowledge of TTOs were also confirmed by academics in both countries:

> "I try to avoid it. Because they're not competent to do the job. Part of the

[26] As a matter of fact, it was found that industry is generally opposed to the presence of TTOs and the increased commercialisation activities by universities for historical reasons. While companies were able to access patents or licenses for free (or more cheaply) before, universities are now much more demanding with regard to IP.

> reason is that they're not experts in my field and the second reason is they ask too much." (university, NL)

> "…it's extremely important that the people that are involved are knowledgeable and well briefed. My experience of places I've been in the past, and from stories I heard, quite often you get university technology transfer people being quite unrealistic with respect to the value of a particular technology or piece of IP, and often you have a university office which covers the entire remit of the university from electronics to computing to life sciences, so it's difficult to have people who are experts in any one area." (university, UK)

The problem of over-valuation has been remarked upon by other studies in the relevant academic literature as well. In a study of commercialisation in biotechnology across European countries, Enzing et al. write that both respondents from firms have acknowledged that the lack of experience, competence and professionalism in dealing with IP in public-sector research leads to an unrealistic idea and therefore over-valuation of patents (Enzing et al. 2004: 379). Glenna et al. (2007) report that the overvaluation can be caused by the complexity of the seed business, which is difficult for most of the public sector members to understand, but also by the focus on revenue generation by universities (p.623). Again, one can argue that the nature of over-valuation has changed from not having enough competencies in managing IP in general to focusing competencies in a few select fields (such as medical biotechnology or ICT).

It has been mentioned in Chapter 2 that academics have differing motivations across the various channels through which they engage in industry relations; in particular research-related factors for collaborations and monetary gains for patenting activities. Trying to combine these two different motivations into one can cause a problem. To be more precise, in the case of UK, many TTOs are involved in contract and collaborative research as well as having responsibilities for managing patents and licenses. Formal engagements of academics with industry involve negotiations about possible commercial outcomes as well, even though there may not be a commercial outcome in most of these activities. This can be one of the causes of the problems arising between the TTO and the academics, as well as between them and industry.

The inexperienced or unskilled TTOs sometimes lead academics to use the 'back door' when they engage in commercialisation activities:

> "My input was we don't put anything on paper. I give you my advice, the company grows, you give back what you think is reasonable… If we had gone through paperwork, it would have taken one and a half to two years before we had something on paper. There'd be disagreements and non-commitments." (university, NL)

The 'back door' effect is not unique to agricultural biotechnology sector and it has been mentioned in the literature before (Link et al. 2007). What is interesting in terms of dealing with TTOs' lacking capabilities, however, is the devolving of commercialisation activities to organisations external to the university, which has implications for both the academic literature and for policy. Two types of external organisations have been identified through the interviews. The first is a specialised technology-transfer organisation, which is independent of the university and does not necessarily have a sector-specific focus. The devolvement of certain technology transfer functions to these organisations does not necessarily mean that the university lacks business capabilities across all fields. On the other hand, it seems to be more effective for central university TTOs to outsource activities to external IOs in fields where there is not much activity:

> "Even organisations like Cambridge, they can't handle that many agbiotech technologies. They're very good at areas they do a lot of work in, which is sort of pharma-related techs. So even the big guys, when they make a plant biotech filing, they struggle to know what to do with it. If they're getting one every couple of years and particularly with the turnover of staff in these offices, often the person who might have handled that technology before has now left". (external IO, UK)

This is similar to MNEs using contract research organisations, as it can be more cost-effective to outsource work during peak or irregular periods instead of maintaining a permanent capability in-house.

The other type of external IO, which is sectorally organised, has been observed in the UK. The first example of this organisation within the agricultural biotechnology field is Plant Biotechnology Limited (PBL). It was established in 1994, originally to protect and exploit IP for the John Innes Centre, but since then it has expanded to become an independent technology-transfer organisation to provide the same services for other research organisations within and outside the UK.

While PBL does not charge its clients for the services it provides, its model is based on the ownership of the IP from the research organisation, whereby the revenues are distributed among PBL, the institute concerned and the individual scientist.

The success of PBL lies in its competencies within the agricultural biotechnology sector. The employees have previously worked in the industry and therefore have a strong understanding of the needs of the industry. As such, they provide a realistic assessment of the technology coming from the research organisations, a weakness from which many TTOs suffer. PBL, which works worldwide, is well regarded by academics as well as industry in both countries:

> "I must say that if you talk to certain people who made the same step but then started to work for themselves, for example PBL in UK, they started in this area themselves, then they started their own company and then you see a change. Because then you're really becoming much more realistic about the value of that technology and sometimes they come to the conclusion that they should not offer technology to us because it's too limited in our area to create added value…" (industry, NL)

> "They know us very well, they've been on site for a long time so I have an ongoing dialogue with them. They always know what the new developments are in my lab…They're experts on plant and microbial IP, they have a worldwide strong reputation, certainly for plant biotech. They've been very good negotiating for me, other companies of this kind they can be pretty aggressive and that's a concern because you don't want to drive the industry away. On the other hand, they get very good deals for us so the patents with [the company] we didn't have any problems getting them filed very quickly, getting the papers out and we didn't have to pay the

> patent costs… because quite often academics will have an idea, unrealistic idea , of what's important. So they don't take everything on." (PRO, UK)

Another sectoral organisation that operates on a much smaller scale is Amaethon - a hybrid model established between University of York and an external IO called IP2IPO. This unit was specially founded to exploit any IP coming out from the Centre for Novel Agricultural Products (CNAP) within University of York. As is explained in the webpage of Amaethon, the university has granted Amaethon the rights to exploit IP in exchange for revenues. It was mentioned in the interview that the person responsible of commercialisation at Amaethon had previous commercial experience at a MNE in the field, which makes it possible to assess technologies emerging from the university.

Commercialisation summary

The previous four functions did not indicate a strong role for intermediary organisations such as TTOs and science parks. In contrast, these organisations do have the potential to play an important role in the commercialisation function provided that they possess certain capabilities.

A strong finding emerging from the interviews is that many of the problems related to TTOs are related to costs and expected income. This supports the existence of what Salter et al. (2009) describe as 'transaction-related barriers', which have been discussed in section 3.2.2.

An important finding regarding IOs is the devolution of commercialisation activities to external organisations specialised in IP management, and particularly in specific sectors. Sector-specific technology transfer companies share the same structure with university TTOs in the sense that they transport information and do not really take part in knowledge generation. Nevertheless, they differ from the university TTOs in terms of the knowledge and experience they have of the particular field, as well as a better awareness of the characteristics and the needs of the sector. This is especially important in the agricultural biotechnology sector where commercialisation opportunities are less frequent compared to some other sectors, such as pharmaceuticals, reducing the opportunities for university TTOs to build the necessary skills and capabilities for the sector.

5.6 Intermediary organisations

In the previous sections I have discussed the empirical findings in the light of the five functions presented in the conceptual framework. In this section I will briefly discuss the empirical findings along the lines of the four intermediary organisation types presented in Chapter 3.

The first category of intermediary organisations were **transporters**, with the main example of this category being university technology transfer offices (UTTO). The findings of this dissertation indicate that these organisations' role is best suited to transactional activities and they generally do not have a significant role in other knowledge-related activities. Nevertheless, the interviews also showed that there are differences among transporters as well, and further differentiation is needed. This shows once more that even within a certain function, there is not a 'one size fits all' solution and further complexities need to be taken into account such as the sector and country, as will be discussed in depth in the following chapters.

Hosts are organisations like science parks[27], in which the IO provides a context that theoretically may facilitate the interactions between university and industry. None of the interviewees reported a significant benefit from being located in a science park in terms of having better or easier access to knowledge by increased interactions with university. As summarised in van Geenhuizen and Soetanto's article (2008), majority of the studies on science parks indicate that the benefits of being located in a science park are not evident and the few studies that find positive effects cannot demonstrate causality. It was discussed in section 3.2.3 that some of the academic literature on science parks shows that there may be benefits for firms located in science parks in terms of increased interactions with university. It would therefore be premature to generalise the findings of this dissertation in terms of the role of science parks. Nevertheless, several interviewees stated that within their sector, they go where the knowledge is, regardless of geographical proximity. This may therefore suggest that the role of science park and similar organisations may vary across industries, as discussed in

[27] While I use 'science park' as the common term throughout the chapter, it includes similar organisations such as technology parks, industrial districts and so on.

section 5.3.

One area where host type structures may present some benefits is providing facilities for smaller firms which may not have the capital resources for such facilities. A company interviewee in the Netherlands mentioned that they benefited from the office facilities in the incubator and another company in the UK mentioned the ease of access to suppliers and labs:

> "...one of the things you have to deal with is suppliers. You need materials. One of the difficulties of doing that as a start-up is to have a critic rating so that you can go to the suppliers. One of the good things about this incubator is you can use the JIC stores. You can begin trading as a company and buy things from the JIC stores which is well supplied. That's really a big plus of being here. There are obviously other facilities on site; we can get access to journals, we can have meeting rooms. There's a lot of equipment that we have which was installed in all the JIC lans which makes maintenance very easy. If we have a problem with our machines, there's an identical one sitting next to it that we can borrow some time on." (industry, UK).

While the results of this study do not indicate a large or important role for science parks in the agricultural biotechnology sector, this may be related to the chosen boundaries of the industries as well as the countries studied. In the Netherlands, there is the Wageningen Food Valley, which hosts several companies located around Wageningen UR.

The third type of IO is the **transformer**, in which the knowledge is ferreted out by the IO from universities and translated into the needs of industry without necessarily producing new knowledge, and consultants were identified as a possible example for this category. Such a need was not expressed by most of the companies interviewed, with the exception of one consultant/ academic who mentioned that he mainly worked for small companies that were focused on application. While there exists agricultural consultants, these mainly work with farmers than companies per se. Based on the very limited number of consultants interviewed for this dissertation, it is difficult to draw a sound conclusion about the role of such organisations in promoting knowledge exchange between university and industry.

The fourth type of IOs is the **translator**, which not only possesses absorptive capacity but also produces new knowledge. Public sector research organisations (PSROs), such as the TNO and the Fraunhofer Institutes, are the main examples included in this category. There are PSROs working in the fields related to agricultural biotechnology as well but this sector is shrinking in the Netherlands and the UK, having been privatised or amalgamated, something that is discussed in further detail in Chapter 7. Although the sector seems to shrink, such intermediary organisations seem to provide benefits for the industry:

> "One of our real strengths has been to take strategic knowledge right through the end user. That requires the ability to do strategic research and then link with the farmer." (PRO, UK)

> "The institutes, their main role is to support UK agriculture bioresearch, they're very research orientated. The universities are as well more or less nowadays, although they have a research base it's not quite at the same level as a research institute." (industry, UK)

The fieldwork conducted for this dissertation presents an interesting finding for this category of intermediary organisations, which is the emergence of private companies that have similar functions to PSROs, with Keygene being an example to such companies. It can be argued that the market – in this case the plant breeding companies - has found its own solution to overcome the weaknesses created in the agricultural research system due to the diminishing role of public sector intermediaries in this field. During the fieldwork, it was observed that Keygene is perceived positively by several Dutch companies because of their particular nature and the strengths this nature brings. However, it should be remembered that since Keygene is a private formed and funded organisation, there may be a positive bias:

> "The advantage of Keygene is that we have collaborated with them for a long time so they know our crops, the specific problems, and in that sense it can be easier to collaborate with them." (industry, NL)

> "What we do there is multilateral projects so in that case we can do things much faster and cheaper." (Industry, NL)

The interviewee from Keygene explained that one of the reasons of success of the company is "the expertise that Keygene built up over the years" and continues to say "Here we have about 100 scientists that have very highly developed knowledge of molecular genetics. So companies that start using molecular markers in their breeding programs, they need the expertise that we already have in house. So they come to us for the technology and for the know-how".

Keygene is an R&D company that was jointly founded in 1989 by a number of Dutch seed companies[28] to provide them with strategic research. Currently, it has two broad areas in which it functions. The first of these is applied research, which includes service work for companies (Keygene interview), especially through their patented technologies. The area it is active in is what is called "upstream innovative research", which includes research in certain areas, sometimes in collaboration with universities. Keygene is well regarded not only by its shareholder companies but also by other companies and academics, as noted by interviewees from both countries.

In addition to the four types of intermediary organisation presented in Chapter 3, a fifth category of intermediary organisation can be identified. I will call this type a **'generator'**, whereby university and industry come together to form an intermediary organisation for a specific period of time. This is based on the example of the programmes such as the Centre for BioSystems Genomics (CBSG) and the Technological Top Institute - Green Genomics in the Netherlands and to a certain extent the Genetic Improvement Networks in the UK, which are described in further detail in Chapter 7. These programmes differ from bilateral collaborative projects between university and industry in the sense that they do address several functions. To give an example, within the CBSG, not only do participants exchange knowledge but there are also networking opportunities, studentships for students, sharing of facilities and commercialisation activities.

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[28] The original founding companies were all Dutch seed companies: De Ruiter Seeds, Enza Zaden, and Rijk Zwaan. Today, there is also a French shareholder, Vilmorin Clause & Cie, and a Japanese one, Takii & Co.

It was discussed in section 2.3 that there is a need to shift the focus from 'technology transfer' to 'knowledge exchange'. The way that generators function suggest that knowledge exchange should be extended further to include co-generation of knowledge where university and industry come together to generate new knowledge. While one can argue that this is part of what the Triple Helix model offers, there is an important difference. Co-generation of knowledge would suggest that university and industry keep their own roles and complement each other, rather than taking each other's role.

Generator-type programmes were considered to be beneficial by both university and industry for a number of reasons. The intermediary institutions usually provide large amounts for funding for a limited time, which in many cases is partially funded by industry as well. The field of research involved usually seems to be of a strategic nature, which has certain benefits. It interests the academics and also provides them with funding opportunities, which is especially attractive since university funding in general seems to be on the decline. For industry, such programmes give them the chance to have access to strategic knowledge in their field without having the burden of the full cost of research, which is instead distributed among several shareholders rather than paying it themselves. Furthermore, they have a chance of monitoring and affecting the direction of the research conducted.

> "...what we've also done as an industry which is unusual because of the nature of our sector and noone's got any money, some of us within the industry put together a priority list for R&D and gave it to all the institutes and universities we can think of and that was done through a loose grouping of ours called the British What Breeders and we created this important list of traits for us... we did this as an industry-wide thing because it gives the researchers a bit comfort that everybody wants this. That was partly because it's very easy for R&D in our opinion to be "flavour of the month" and certain areas get neglected...what we'd like to is to be more involved in a steering group capacity [referring to government-funded projects]. We're very happy to be involved in these projects if they want an industrial person to sit on the project committee and that does sometime

> happens. (industry, UK).

> "Now we're starting TTI-GG. An initiative I was involved in writing the business plan. This is a program of much more strategic nature where the companies have the leads to determine the research questions, they ask certain research groups or companies to be involved in the program and come up with the solutions. That's a bit the other way around where the initiatives usually come from research programs." (academic, NL)

On a smaller scale, a company R&D manager mentioned about a Carbohydrate Competence Centre "with Groningen University, TNO Quality of Life...WUR, and a couple of large companies" and said that their interest in that

> "...is to ask the centre more fundamental questions behind the possibilities that we develop ourselves so from that we can go to the next step. Because we don't have the resources to really understand why certain things happen, but we could definitely use that knowledge to develop the next step and next generation....We are steering the wheel to determine what projects they will work on..." (industry, NL)

These institutions are close to the type of intermediaries that van Lente et al. (2003) describe as working at a systemic-level rather than focusing on bilateral relations. While their examples of system level intermediaries do not include the institutional designs above, it can be argued that generators are considered to be more beneficial by the interviewees because they involve a combination of funding, networking opportunities and knowledge exchange in addition to commercialisation activities.

5.7 Chapter summary and links between the results and the relevant academic literature

In this chapter, the first part of the empirical results was presented in relation to the five functions defined in the conceptual framework. For each function I have tried to establish whether there was a relation between university and industry within the agricultural biotechnology sector. Having an understanding of whether a relation exists, why it exists, and how it happens gives the possibility to assess what advantages and disadvantages intermediary organisations present for this relation, if they are involved at all. I have then discussed the empirical findings along the lines of the four intermediary organisations to see whether particular types are better suited to fulfil certain functions. Furthermore, a new intermediary type was derived from the findings, the 'generator'.

In Chapter 2 it was argued that, within the Systems of Innovation framework, innovation takes place through learning, knowledge accumulation and interaction between the different components of the system, and there is not a linear flow of knowledge from university to industry. This study confirms this notion; generator-type intermediaries, which were positively perceived by the majority of the interviewees, provide an interactive environment and allow learning and knowledge accumulation.

Other intermediaries lacking certain skills appear to create more 'noise' in the relationship between university and industry rather than serving as a catalyst. The most obvious examples of this were university technology transfer offices, which in many cases lacked the necessary skills in agricultural biotechnology.

Chapter 2 briefly reviewed two theoretical attempts to explain university-industry relations. According to the first of these, 'The New Production of Knowledge', there has been a shift from Mode 1 to Mode 2 knowledge production, and it is also argues that universities are playing a smaller role in knowledge production (section 2.2.1). While the interviews generally supported the argument that the knowledge production takes places in a more transdisciplinary and heterogeneous context, it is evident from the interviews that universities still conduct a certain type of research that cannot be carried out by industry.

Regarding the role of universities, according to the Triple Helix model the university, industry and government spheres are overlapping now in a new form of knowledge production where they partially assume each other's roles. While it might be true that there are overlapping areas, the interviews have strongly indicated that there is still a pronounced division of labour between university and industry. While industry expects universities to conduct fundamental research, universities are not interested in the development end of the knowledge spectrum and are not considered to be competent for this kind of work.

The other important argument associated with the Triple Helix model is that universities now have a new 'third mission' of contributing to the economy. This concept has been observed during the interviews, although the perspective was different. Interviewees both from universities and industry have complained that the contribution to the economy is closely associated with quantifiable indicators such as the number of patents and the income generated, which they consider to have a harmful effect. The 'third mission' of universities, which is increasingly emphasised, seems to have detrimental effects by straining university-industry relationships and by pushing universities towards the more applied side, which does not match the needs of industry.

Another emerging theme from the empirical results is a possible differentiation between intermediary organisations and intermediary institutions. The interviews showed that certain programmes such as the LINK and CASE studentships[29] in the UK facilitate the knowledge exchange between university and industry. Recalling the differentiation between 'organisations' and 'institutions' as discussed in Chapter 2, these programme can be considered as institutions.

In section 2.3 a differentiation was made between 'technology transfer' and 'knowledge exchange'. It can be argued that the variety of intermediary organisations analysed in this dissertation reflect these distinct perceptions as well. Technology transfer tools include aiming to equip the research base with increased capabilities for the protection and exploitation of intellectual property. These include funds for building the technology-transfer infrastructure or start-up capital. In terms of the intermediary organisations considered, it can be argued that the transporters and hosts are part of the technology transfer tools. Knowledge-exchange tools aim to bring the university and industry closer together for collaborative projects. These include studentships with industrial funding and supervision, and large programmes funded at least partially by government where academics and industry work together. I consider generators and intermediary institutions to be included under knowledge-exchange tools.

[29] These programmes will be discussed in further detail in Chapter 7.

It is more problematic to determine where the transformers and translators would be included. If the examples of consultants and PSROs are taken, they do not co-generate knowledge with industry as in the case of generators. However, they do not directly *transfer* a pack of information from one domain to the other, instead, they are able to source, filter and absorb knowledge and to transform or translate it according to the needs of the recipient. It is therefore more appropriate to consider them under the category of knowledge exchange tools.

Given the empirical results of this dissertation up to this point, is it possible to make policy suggestions and to say, for example, that there is no need for university technology transfer organisations or science parks? It is not; as the following two chapters will argue, the characteristics of a sector as well as the country will affect what type of intermediaries have a role or not.

CHAPTER 6: TECHNODYNAMICS

The previous chapter presented the results of the interviews in relation to the five functions, which were derived in Chapter 3 as a part of the conceptual framework. One of the results emerging from this chapter was that sector specific characteristics affect university-industry relations and therefore the role of intermediaries. To recap briefly, the relatively low profitability of the agricultural biotechnology sector and the changing role of public sector research organisations are two significant examples of such characteristics. In this chapter, I will present a deeper analysis of the agricultural biotechnology sector by making use of the technological regimes concept borrowed from the sectoral systems of innovation (SSI) literature, in relation to university-industry relations and intermediaries, which was briefly introduced in Chapter 2. Coriat et al. (2003) argue that the literature shows that science-based sectors can have diverse configurations and the 'co-determination' and 'co-evolution' of technological and institutional regimes is important. Together with the analysis of the institutional context in Chapter 7, this chapter will look at how these two dimensions specifically shape the role of intermediaries.

It is also important to make the aim of this chapter clear and to remind the reader that, while looking at the agricultural biotechnology sector, this dissertation is not about the sector itself. In the foreground of this dissertation lie the policies, and the choice of the sector is a means to discuss the roles of intermediary organisations and their advantages/disadvantages as policy tools, and the resultant need to take sectoral characteristics into consideration. Therefore, the focus is on the agricultural biotechnology sector to provide a cross-sectional view of university-industry relations (UIR), rather than focusing on the agricultural biotechnology sector primarily in which UIR is one of the many elements that affect the sector. However, the findings of the dissertation still have policy implications for the sector studied, as will be discussed in the last chapter.

The interviews demonstrated that there are sector-specific issues that are common to both countries and were voiced by both industrialists and academics. Broadly, these are issues around intellectual property rights, profitability and the supply of human resources. Other elements such as the configuration of the research base and state policies are of importance to UIR in the sector as well, but they are influenced by the country and therefore they will be discussed in the following chapter.

While the SSI framework is useful in understanding the characteristics of the sector in a more systemic manner, it is not suitable as the main framework for a couple of reasons. Firstly, my focus is on certain activities of firms - namely R&D - and other activities such as manufacturing and sales are not considered in depth in this dissertation. This is mainly due to the previously stated reason that the focus is on the policy dimension rather than the sector itself. Secondly, while SSI takes certain institutional features into consideration, the scope is limited to institutions that are linked to the sector. It is for this reason that National Systems of Innovation is a more suitable framework for the cross-country comparison, which includes institutional factors that may have indirect effects on the sector.

One of the main difficulties within this dissertation is specifying the borders of the sector, and a theoretical discussion of this in relation to sectoral systems of innovation and technological systems can be found in Section 2.1.3. Here, I will add a few more practical explanations regarding the choice and limitations of the sector. The limitation of the sector as drawn within the PITA[30] project was taken as starting point in determining the companies to be considered for empirical research. Within this project, Bijman writes that the main groups of companies involved with agricultural biotechnology are agrochemical companies, seed companies and new biotechnology firms (2001: 83). Agricultural biotechnology within this chapter will refer to the consolidated sector comprising agrochemical and seed companies. The seed companies taken into consideration work mainly in field and horticultural crops and exclude ornamentals. While ornamentals sector is very large in the Netherlands, it is exceptional and not representative of the other EU countries; 90% of the ornamentals within the EU are exported by the Netherlands (Dons and Bino, 2008: 120). Furthermore, according to Alston et al. (2006), research in agricultural biotechnology has been mainly directed towards

[30] PITA: Policy Influences on Technology for Agriculture.

field crops rather than horticultural products and perennials[31], although some of the largest programmes in the Netherlands are on potatoes and tomatoes .

The next sections will first introduce three concepts from the technological regimes literature, namely opportunities (6.1.1), appropriability (6.1.2) and cumulativeness (6.1.3), relating them to industries analysed in this dissertation and discussing the changes in these conditions in Section 6.1.4. I will compare the agro and pharma fields in Section 6.2 to show how the same technology can have very different applications across industries and affect the way that intermediary organisations function. I will also show that the institutional configurations matter, making a brief comparison of Europe and the USA in Section 6.3. Finally, I will summarise the findings of the chapter in Section 6.4 and make an attempt to connect the configuration of technological regimes with the functioning of different intermediary organisations.

6.1 Technological regimes

The term 'technological regimes' was apparently first put forward by Nelson and Winter (1982) to describe the learning and knowledge environment in which firms operate. In a similar manner, Malerba and Orsenigo (1997) propose that innovative activities within sectors are related to technological regimes "describing the technological environment in which firms operate" (p.94). They then present three properties of technologies that make up the regimes: "opportunity and appropriability conditions; degrees of cumulativeness and technological knowledge; and the characteristics of the relevant knowledge base" (ibid). In the following section, the agricultural biotechnology sector will be analysed in terms of these proposed characteristics of technological regimes. It should be noted, however, that the empirical and secondary sources allow an indication of where the sector lies with respect to these characteristics rather than providing more specific measurements, partially because it is difficult to quantify these terms and partially because of the difficulties in defining and bounding the sector as mentioned earlier.

The literature on agricultural biotechnology, agrochemicals and seeds is rich in

[31] Perennials are plants that live for more than two years, some examples of which are shrubs, trees and some flowering plants.

terms of discussion of such issues as the industry structure and legal protection, although the discussion is similar albeit rather fragmented. A particular study that is worth mentioning here is the PITA project, which looks at the European agricultural biotechnology, seeds and agrochemical companies. However, this chapter makes an original contribution by making an initial attempt to analyse this sector through the lens of the technological regimes concept. The theoretical and policy relevance of taking such an approach will be discussed in the synthesis and conclusion chapters.

In the following three sections, I will describe the three elements that make up technological regimes – opportunities, appropriability and cumulativeness - and discuss the changes in the sector through the use of these elements.

6.1.1 Technological opportunities

Opportunity conditions "reflect the easiness of innovating for any given amount of resources invested in search", and they have four basic dimensions; level, variety, pervasiveness and source (Malerba and Orsenigo 1997: 94). *Level* refers to the "probability of innovating for a given amount of resources invested in search"; *variety* refers to the variety of technological solutions, approaches and activities; *pervasiveness* is related to the applicability of new knowledge to different products and markets; and *source* refers to where the opportunity conditions are to be found, such as universities, instrumentation and so on (ibid). Or in the words of Dosi et al., opportunities capture "the width, depth and richness of the sea in which incumbents and entrants go fishing for innovation" (2006: 1119). Although I will not be able to provide quantitative measures for these elements[32], I will discuss the opportunity conditions in the seed and agrochemical industries, and how these have changed through the emergence and application of agricultural biotechnology using secondary sources from empirical studies in the academic literature, statistics and interview data, where available.

The agrochemical sector has traditionally been highly science–dependent and product innovation has depended on the discovery of new active ingredients.

[32] As Cohen writes, "there is no consensus on how to make the concept of technological opportunity precise and empirically operational" (2010: 172) and the existing econometric attempts are beyond the limits of this dissertation.

Initial discovery of active ingredients relied on “random screening” of molecules, which was improved by the discovery of new techniques such as high throughput screening. As Hartnell (1996) writes, “in the early days new active ingredients created new markets”, and with little competition, innovation in the field peaked (p.381). Tait (2007) writes that, although high throughput screening and combinatorial chemistry were path-breaking technologies, they have not changed the underlying incremental innovation model in the pharmaceutical and agrochemical industries (p.264). Furthermore, the technological opportunities provided by the new techniques have not been endless and the rate of new active ingredient discovery is stagnating. Joly and Lemarie (2002) write that an agrochemical company now has to test about 200,000 new molecules to identify a commercially successful product compared with 1000-1500 in the 1950s (p.261). Based on a study of six large companies, McDougall (2003) gives a similar result by showing that the amount of synthesised molecules has risen from 52,500 in 1995 to 140,000 in the 2005-2008 period, whereas the number of products registered was the same: namely one. However, it would be inaccurate to claim a direct link between this information and the nature of the technology itself considering that regulations have become stricter and costlier over time, as well.

Seed companies, on the other hand, tended to be family-owned businesses that have relied on more traditional techniques (Bijman 2001: 85). Improvements to seeds included germplasm collections and the identification of superior plants and hybridisation for the improvement of germplasm. It should also be mentioned that public sector research organisations played an important role in developing, maintaining and supplying germplasm collections. While some of these techniques, which are less ‘technological’, are still an essential part of the seed business, the emergence of biotechnology has provided new opportunities for plant breeding through techniques such as marker-assisted selection and genetic modification (transgenesis). However as mentioned by some interviewees, there are still very traditional tasks in the process of plant breeding such as crop selection on the field, which cannot currently be conducted by technology and which needs trained people.

With respect to the new technological opportunities arising from biotechnology, it was initially the seed companies that took advantage of these technologies for innovation rather than the agrochemical companies[33]. Nevertheless, agrochemical companies subsequently captured the technological opportunities used by seed companies through the acquisition of seed companies as well as marketing complementary products for seeds. To give an example, Graff and Zilberman (2007) write that in a period when chemical sales by European firms have decreased, those of the US firms have increased, which was likely to be driven by selling packages of genetically modified seeds and complementing chemicals[34] (p.252). With the emergence of both new chemical and biological techniques, the source of the new technological opportunities was mainly universities.

Among the different characteristics of technological opportunities, the source has a particular relevance to the role of intermediaries as changes in the source of opportunity will tend to affect the firms in terms of their demand or need for university-industry relations. When the source of technological opportunities is universities, one would expect to see increased interaction between the two sectors. Indeed, one of the reasons for industry to keep in touch with universities is to identify new or potential sources of technological opportunities. When the opportunities arise through the development of in-house capabilities, there may be less need for such interaction[35].

6.1.2 Technological appropriability

Appropriability conditions refer to "the possibilities of protecting innovations from imitation and of extracting profits from innovative activities", and they have two main dimensions: level and means (Malerba and Orsenigo 1997: 95). The first refers to the different levels of appropriability across industries, whereas the latter refers to the variety of mechanisms that firms can employ for protecting their innovations, such as patents, secrecy agreements and the like. Both of these elements are particularly important to this dissertation as university technology

[33] Although one can argue that biological (internal) protection is the new product type of agrochemical companies as opposed to the older chemical (external) protection, these companies are still dependent on the sales of their chemical products.

[34] An example of such a complementary package is glyphosate and glyphosate-tolerant soy beans. Monsanto produced genetically-modified glyphosate-tolerant seeds to be marketed with its Roundup herbicide containing glyphosate.

[35] As an interviewee from a MNC said, "...our chemical research is almost entirely in-house…in the biotech arena it's a bit different because there's a lot more research, it's not so industrialized".

transfer offices, which are one of the most common forms of intermediaries, are mainly responsible for transaction-related activities and most of the complaints brought up about these organisations by the interviewees were in these activities. Therefore, if one can understand the appropriability structure of an industry, better mechanisms for managing transactional activities can be devised. The following paragraphs will analyse the agricultural biotechnology sector along these two dimensions.

As a highly science-dependent industry, agrochemicals industry has relied heavily on patent protection and is therefore a sector with a relatively high appropriability. Tait (2007) writes that the sector reached maturity once chemicals for easy targets have been developed (p.264). The patents are dependent on the discovery of new active ingredients, and as mentioned at the beginning of this chapter, the efforts needed for the discovery of commercially successful active ingredients have not become any easier. Corresponding to the stagnation in the rate of discovery of new active ingredients, patent protection on existing products has started to run out as well, leading to the emergence of the so-called generic companies, adding to the competition in the market. This situation is not limited to agricultural chemicals; the same problem exists in the pharmaceutical sector as well, with stories about large pharma companies losing their patent protections and now having new drugs to replace them (Boyle 2010). It can be argued that while the appropriability conditions – the possibility to take out patents - have not decreased per se, the technological opportunities leading to patentable products have decreased.

As opposed to agrochemicals, the seed sector traditionally did not have particularly good appropriability conditions. As cited by Dosi from Nelson (1986), agricultural sector was one with "low commitment to research and innovation, despite significant scientific and technological opportunities, due to the lack of satisfactory appropriability conditions" (1988: 1141). The first form of proprietary legislation regarding plant breeding was the Plant Patent Act of 1930, enacted in the US, which provided a very narrow scope for the protection of new varieties[36].

[36] While the 1930 Act made it possible to patent new plant varieties, it was limited to asexually propagating species, which meant the exclusion of crops like wheat, maize, barley, oilseeds, rice,

In 1970, the Plant Variety Protection Act was enacted in the USA, which extended the protection to sexually reproduced varieties as well. In Europe, a similar protection was introduced in 1961 through the convention for the Protection of New Varieties of Plants (Wright and Pardey, 2006). Both of these acts required a demonstration of usefulness in addition to conditions on novelty and distinctiveness for acquiring plant breeders' rights. According to Murphy (2007), the establishment of Plant Variety Rights led to the emergence of the early seed entry companies such as the ones in the Netherlands.

The final stage of legislation regarding proprietary protection in the agricultural sector was the extension of utility patents to living organisms - including plants- in the USA in 1985, following the landmark court case of Diamond vs. Chakrabarty in 1980, which resulted in the patenting of a human-made bacterium. This has given the seed companies a much larger set of rights over plants[37]. The European Patent Convention does not allow patents for plant variety or biological processes.

An important feature of the Plant Variety Protection (PVP) is the 'breeders' exemption', which allows breeders to use a variety as a base for developing new varieties, as well as using the variety for research purposes and for acts done privately and non-commercially, without having to get permission from the title holder. This in turn limits the appropriability of returns from innovations in plant varieties and it is therefore considered to be a weak appropriability system by some (Schenkelaars Biotechnology Consultancy 2005: 46). There is a dedicated stream of literature on the advantages and disadvantages of different systems, in particular in connection to development issues, but such issues lie beyond the limits of this dissertation.

Several authors have discussed the role of PVP in stimulating private R&D in agriculture, with a difference between European and US-based studies. In the US, where utility patents are allowed for plants, the role of PVP seems to be more limited (Janis and Kesan 2002). On the other hand, in Europe where PVP

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cotton and more commercially important crops (Murphy 2007: 106).

[37] Better appropriability conditions should theoretically incentivise companies to invest in more R&D, but some of the studies in the literature argue that plant variety rights have not led to increased R&D in the sector (Alston & Venner, 2002) and partial or limited exclusivity in patents may be enough (Rubenstein, 2003) .

constitutes the main form of appropriability, it is suggested that PVP contributed to the increase of private R&D in agriculture.

Murphy (2007) puts forward two barriers to making significant profit from new varieties: the biological one of preventing farmers from saving seed and the regulatory one of ensuring maximum legal ownership of the seed (p.106). As he notes, the second one is easier to achieve: "…it was simply a matter of persuading the right people to enact the right legislation (i.e. lobbying), which is normally a lot simpler than manipulating a complex biological system… " (p.107). While the US system provides more opportunities for legal ownership of the seed, the European system is relatively more restricted with the opportunities it provides for appropriability, as there is not utility patent protection for living organisms.

To summarise, in terms of legislation for the protection of new discoveries, the appropriability conditions in the seed industry have generally improved[38] over time (albeit to different levels across countries), whereas in the agrochemicals sector it has stayed broadly the same. On the other hand, the main improvements in the seeds sector have been towards the enhancement of seeds, to increase productivity in plant breeding, a goal that the agrochemical industry has been working for through chemical methods. Therefore increased appropriability conditions in the seeds sector was one of the major factors leading to the acquisition of smaller firms in this sector by the larger agrochemical companies.

The connection between appropriability conditions in a sector, along with other factors, and corresponding policy instruments has been discussed before. In his 1984 paper, Pavitt presents a taxonomy of sectoral patterns and suggests three categories of firms: supplier dominated, production intensive and science-based. Based on this taxonomy, Martin and Scott set out a typology of innovation modes, sources of sectoral innovation failures and related policy instruments (2000: 439). According to this typology, the main mode of innovation in agriculture is the "application of inputs developed in supplying industries" which face the problems

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[38] This improvement is from an industry perspective in terms of having a system for intellectual property protection, regardless of whether it is used or not. Whether more stringent IP protection can be considered as an 'improvement' from different perspectives, such as development, is a subject of ongoing discussion. An important article regarding the possible negative consequences of IPR for technological development is by Heller and Eisenberg (1998).

of small-firm size, large external benefits and limited appropriability. The corresponding policy instruments are low-tech bridging institutions such as extension services in order to facilitate technology transfer. Biotechnology and chemistry, on the other hand, are based on the applications of high-science-content technology, and they face the problem of knowledge originating outside the commercial sector, where the creators may not recognise the potential applications. According to the authors, this problem is addressed by high-tech bridging institutions, such as university-industry research parks or government laboratories that "facilitate the diffusion of advances in basic research from academic research operations to private sector" (p.444). However, as has been argued throughout this dissertation, it is debatable to what extent organisations of the former kind are facilitating the diffusion of knowledge. On the other hand, the latter kind, which is included within the translator type intermediaries, can indeed play a role in the diffusion of knowledge.

Land-grant universities in the US, established by the Morrill Acts of 1862 and 1890, have traditionally conducted significant amounts of agricultural research as well as carrying out extension services. Extension was a 'knowledge transfer' process whereby end-users (farmers) were informed about new agricultural research results. Extension roles in the Netherlands and the UK were carried out by public sector organisations such as ADAS[39], before they were privatised or amalgamated. At the same time extension agencies were transforming, high-tech bridging organisations have started to emerge and to increase in number, due to institutional changes and the rise of biotechnology. With the previously mentioned transformation of the agricultural biotechnology sector towards a more science-based content, one would expect increased university-industry relations and therefore a positive role for the emerging high-tech bridging organisations. However, based on the interviews and academic literature, it can be argued that in the case of agricultural biotechnology the decline of the public sector had negative effects on industry and not so positive ones with the high-tech bridging organisations either. This can, in part, be explained by the low appropriability

[39] In the UK, ADAS (Agricultural Development and Advisory Service) originally dated back to 1946, serving under the Ministry of Agriculture, Fisheries and Food, and was privatised in 1997 to serve as an environmental consultancy.

conditions of agricultural biotechnology sector in Europe and one can perhaps expect to see a different situation in the US where the appropriability conditions are better for industry and where extension agencies still exists, suggesting a better distributed and better balanced intermediary system.

While it has been argued above that stricter appropriability conditions in agricultural biotechnology may lead to more innovative activity, within industrialised countries, this cannot be generalised for all sectors and countries. As a matter of fact, Dosi et al. draw attention to the relation between appropriability and the rate of innovation and make three critical remarks; appropriability conditions is only one of the factors affecting the rate of innovation; appropriability is likely to display a threshold effect where above this threshold stronger appropriability conditions may not display positive effects; and there is no clear evidence of a positive relationship between stricter IP regimes and rates of innovation (2006: 1111). Considering these drawbacks, it is doubtful whether stronger protection regimes, such as utility patents in the US, for agriculture would promote innovation in this sector. This also relates back to the discussion about policy solutions for market failure vs. system failure approaches and as the next chapter will show, there are perhaps alternative institutional solutions to enhance innovation in the agricultural biotechnology sector.

6.1.3 Technological cumulativeness

Malerba and Orsenigo (1997) identify three sources for technological cumulativeness: learning processes and dynamic increasing returns at the technology level, organisational sources, and previous successes (p.95). Within plant breeding, the dominant source of cumulativeness has been the learning processes accumulated by the public sector and breeders, as well as special collections such as germplasms that led to more varieties. Facilities within the plant-breeding sector are probably more related to the development of the varieties generated rather than being the source or locus of innovations. Nevertheless, human-embodied capabilities that are of crucial importance can be considered as a source of organisational cumulativeness.

Within the agrochemicals sector, the cumulativeness has been more dependent on organisational sources. Large chemical companies have built in-house facilities and capabilities to conduct research. McKelvey and Orsenigo (2001) explain that in the period between the second world war and the early 1980s, the pharmaceutical industry had a 'target rich' environment but had very little knowledge about the underpinning biological knowledge underlying the specific diseases, resulting in a 'random screening approach' (p.9). It was the same for the agrochemical industry. Although the discovery of active ingredients has been facilitated by the emergence of new techniques such as combinatorial chemistry and high-throughput screening, it is debatable whether this was a source of cumulativeness in terms of learning processes, as the problem of not knowing the underlying biological reasons was still not resolved.

Malerba and Orsenigo (1997) write that technological cumulativeness is associated with "high degrees of stability in the hierarchy of the innovative firms and low rates of innovative entry" at the sectoral level (p.98). This certainly holds for the agrochemicals industry, which is dominated by large MNEs with corporate R&D labs. While the seed sector has not previously been dominated by large companies, the industry is built around 'improvement' of plant varieties rather than the invention of plants, so to say. Therefore it can be argued that the emergence of biotechnology and its application into agriculture has improved this cumulativeness, rather than causing a disruption.

Biotechnology is considered to be a newly emerging paradigm in general by several authors[40] and also for the chemicals industry as it has brought about "a whole new area of knowledge and theoretical understanding, a new set of experimental procedures…and a new array of skills" (Walsh and Lodorfos 2002: 281). As Powell et al. write, biotechnology "represents a competence-destroying innovation because it builds on a scientific basis (immunology and molecular biology) that differs significantly from the knowledge base (organic chemistry) of the more established pharmaceutical industry" (1996: 117). Emerging from the university sector, it was primarily absorbed by dedicated biotechnology firms and some seed companies, which had the necessary absorptive capacity to utilise this technology. As opposed to the development of agrochemicals industry, where in-house capabilities were developed by companies, MNEs had a head-start in

[40] Among them are Balmer and Sharp (1993), Dalpe (2003) and Orsenigo et al. (2006).

agricultural biotechnology mainly through a series of mergers and acquisitions and because of their dense external networks of academics and dedicated firms, with a few exceptions (Walsh & Lodorfos 2002: 282). While the cumulativeness has not changed for chemical-based products, a change occurred for biological-based products where knowledge was initially acquired through organisational sources. It is in the last 10 years or so that agrochemical companies have started to build in-house capabilities for biotechnology-based products.

Technological cumulativeness, as the name implies, is dependant on the knowledge generated before, and according to Malerba and Orsenigo (1997) 'learning processes and dynamic increasing returns at the technology level' are one of the sources of technological cumulativeness. It is therefore necessary to not only sustain physical cumulativeness (such as germplasm collections) but also cognitive cumulativeness, which is dependent on the supply of trained human resources. It has been mentioned by several interviewees, especially in the UK, that the number of people and the amount of resources going into agriculture has been declining. A report by Schenkelaars Biotechnology Consultancy (2005) also indicates that some companies in Europe, although not in the US, are suffering from difficulties in finding sufficient numbers of 'classical' plant scientists and breeders (p.4). The relevance of this problem to intermediaries will be discussed at the end of this chapter.

6.1.4 A change in the dynamics

In the previous three sections I have talked about three elements that make up the technological regimes - opportunities, appropriability and cumulativeness - and how these have changed within the agrochemical and seed industries with the emergence of agricultural biotechnology. Malerba and Orsenigo suggest that the change in the structure of innovative activities can be related to the distinction between Schumpeter Mark I and Mark II innovations (1997: 84). Schumpeter Mark I is characterised by "creative destruction" where new firm entry is easier and therefore entrepreneurs play a major role. It is marked by high technological opportunities, low appropriability and low cumulativeness. Schumpeter Mark II, on the other hand, is characterised by "creative accumulation", where large established firms play a major role and there are barriers to new firm entry (p.89).

With the emergence of biotechnology, one could expect a shift from Mark II to Mark I as dedicated biotechnology firms have emerged providing new technological opportunities for the existing industries. However, even with greater technological opportunities, the possibility of exploiting those opportunities also depends on other factors such as the costs of product development, registration and so forth (Murphy 2007:11). As Bijman notes, the high costs of product development, registration and testing[41] meant that the companies involved in the sector were generally large ones (2001: 85), and this might be the reason why new firms in the field have not caused a shakeout of large and established firms in the chemical industry (Walsh and Lodorfos 2002: 274). The model in agricultural biotechnology cannot therefore be exactly described in terms of a shift from Schumpeter Mark II to Mark I in the Netherlands and UK; despite increased levels of opportunity or appropriability, the emergent technologies have been rather quickly absorbed into the existing large firm structure, without the real emergence of a dedicated (agricultural) biotechnology firms sector, as in the case of medical biotechnology.

6.2 Agro vs. Pharma

Nightingale and Martin (2004) write that over the past decade a 'revolutionary' model of technical change based on biotechnology has been promoted by a variety of groups, particularly in the medical field (p.564). The 'revolutionary' image of biotechnology found supporters in the agricultural field as well. As well as contributing to general welfare of the society, biotechnology has been considered as many as an academic field/technique that can make significant contributions to the economy. The emergence of spin-offs and start-ups in the biotechnology field has contributed to this view. As a science-based field, university-industry relations in the field are dense, as has been noted by several authors in the academic literature (e.g. Kenney 1986, Orsenigo 1989, McKelvey et al. 2004). Most of the early works looking at university-industry relations in biotechnology did not differentiate these relations according to the various industries to which biotechnology applied, and they used pharmaceuticals as the most common

[41] According to McDougall (2003) the expenditure for development and registration of a new crop protection product has risen from $23.1m during the 1975-1980 period to $157m during 1990-1995 period, and to about $256m in the 2005-8 period (McDougall, 2010).

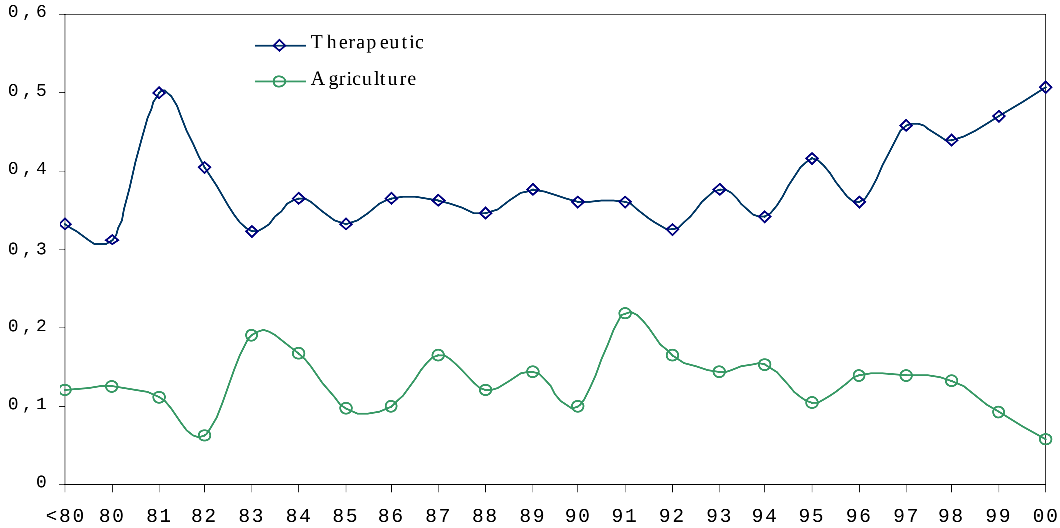
example. Nevertheless, the application of biotechnology varies greatly across industries. The OECD definition of biotechnology is "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods, and services" (2005: 9). This is a very broad definition and it would therefore be wrong to consider biotechnology as a whole sector, rather than as an enabling group of techniques, similar to ICT.

In this section I will discuss the similarities and differences between the agrochemical and pharmaceutical industries to show how two sectors that have been affected by the emergence of biotechnology differ in the way that they related to universities. The reason behind choosing pharmaceuticals is two-fold; firstly, these two sectors have moved rather close to one another at a certain period, and secondly, although under the same biotechnology umbrella, they are quite different to each other in terms of their technological regimes.

Prior to the emergence of modern biotechnology, the pharmaceutical industry had larger similarities to the agrochemical sector in terms of being dependent on the discovery of new active ingredients, as has been explained in section 6.1.1. Being science-based, both sectors relied heavily on R&D and patent protection (Hartnell 1996: 379). As mentioned earlier in the chapter the emergence of more advanced methods such as high-throughput screening and combinatorial chemistry has initially increased the rate of active ingredient discovery. The emergence of modern biotechnology has provided new opportunities for innovation in both sectors. Within the pharmaceutical area, the first to exploit biotechnology were new biotechnology firms (NBFs), which were usually formed as a collaboration between scientists and professional managers (McKelvey et al. 1004: 92). These firms were generally lacking in the agricultural sector - within Europe at least, with a few exceptions - and it was large and established firms that got most involved with biotechnology (Huttner et al. 1995: 33). As mentioned previously, the appropriability conditions for agricultural biotechnology are stronger in the USA compared to Europe. Considering the examples of many NBFs being formed based on a patent, it would not be wrong to assume that the lack of a similar IP regime in European agricultural biotechnology is one of the reasons to explain the lack of a populated NBF sector.

A report by Allansdottir et al. (2002) on innovation and competitiveness in European biotechnology shows that the proportion of European dedicated biotechnology firms (DBFs) in agriculture is considerably smaller than the number in therapeutics (Figure 6.1). Furthermore, the authors add that the proportion of DBFs in agriculture has decreased from about 15% in 1995 to less than 5% in 2000, probably being affected by the implementation of stricter regulations on GM food.

Figure 6.1: Proportion of European dedicated biotechnology firms active in therapeutics and agriculture, by year of foundation



Source: Allansdottir et al. (2002, p.36)

The relationship between agrochemical and pharmaceutical companies has been one of a short-term 'marriage' followed by 'divorce' (Graff and Newcomb 2003; . An initial merger of the agro and pharma divisions within large chemical companies was a means of capitalising on potential synergies, which worked in the early stages on the screening of novel chemicals (Carr, 2002). However, agriculture has higher opportunities for the use of GM organisms (Tait et al. 2001: 10), which shifted the direction from a chemical-based external protection to a biological-based internal protection system. In combination with a fear of the adverse effects of public reaction to agrochemicals and pharmaceuticals, this differentiation eventually led to a demerger of the agro- and pharma- divisions in many companies (ibid, p.243). Zeneca is one of the companies that have gone through such a process.

Pharmaceutical and agrochemical industries also differ in the importance given to different appropriability mechanisms. It has already been mentioned in section 6.1.2 that agricultural sector makes use of a sector-specific appropriability mechanism called the plant variety protection, especially within Europe. On the other hand, pharmaceutical industry is one of the rare industries where studies showed that patents have an important role. Furthermore, Evans and Powell (2006) explain that one of the crucial differences between the medical and agricultural biotechnology is that while a patent is valuable on its own for the former, it is not the case in the latter. They explain that the demand is inelastic and pricing is not a competitive issue in medical biotechnology as it is directly related to humans. On the other hand, the primary consumers in agricultural biotechnology are farmers where the successful agricultural products are directed at enhancing the product. Furthermore, techniques from biotechnology compete with alternative solutions such as agro-chemicals, limiting the profitability (p.15). This adds further difficulties of using patents as a means of enhancing innovation.

The differences in appropriability regimes are reflected in the profitability of the sectors as well, an issue raised by the interviewees as mentioned in chapter 5. The interviewees mentioned that the agrochemicals sector is not as profitable as the pharmaceuticals, which is supported by statistics as well (Table 6.1). In 2007, the total sales of top 10 firms was \$14,785m for seeds and \$34,396m for pesticides, standing in the shadow compared to \$276,352m for pharmaceuticals (ETC Group, 2008). Nevertheless, it would not be possible to explain this large difference solely in terms of the different appropriability regimes. The next section will discuss that in the US, utility patents are granted for agricultural products as well, meaning a stronger appropriability regime compared to Europe, and yet the even the largest agricultural biotechnology firms in the US, like Monsanto, have much lower sales than their pharmaceutical counterparts.

Table 6.1: Comparison of the sales of the top 10 companies in Pharma, Seeds and Agrochemical Markets

$m	Pharma	Seeds	Agrochemicals
1995	84980	5520	23673
1996	91048	6031	25219
1997	104928	7429	26216
1998	--	5497	26466
1999	--	7196	--
2000	149682	7194	25575
2001	--	7157	23034*
2002	194807	7333	22275
2003	--	--	26052
2004	243300	11150	29566
2006	276352	12559	30476
2007	263493	14785	34396

Source: compiled from various sources by the author

Looking at the similarities and differences between two sectors, it is possible to suggest that they have different technological regimes and therefore will interact with intermediaries differently. Both sectors have been affected by increased technological opportunities through the emergence of biotechnology, and therefore increased technological appropriability. Although it is not possible to make a claim about the USA within this dissertation, it is possible to suggest that within Europe the utilisation of the increased appropriability conditions differs between the agricultural and medical biotechnology sectors mainly due to the respective institutional frameworks, which connects with the next chapter.

With respect to university-industry relations in the sector, it is possible to think that increased technological opportunities combined with existing high appropriability conditions have resulted in more fruitful – and hence the exemplary - university-industry relations within the pharmaceutical sector. The agricultural biotechnology sector in Europe, on the other hand, suffers from lower appropriability conditions.

6.3 Importance of the institutional context

As mentioned previously, the next chapter will look at how the institutional structures in the Netherlands and the UK affect university-industry relations in the agricultural biotechnology sector. However, both the Netherlands and the UK share some common European characteristics that affect these relations and consequently the role of intermediaries in these countries. While comparing these two countries will reveal the fine details about the role of intermediaries, a brief comparison of the European and the US agricultural biotechnology sectors will perhaps help the reader better understand how much institutions do matter.

It can be argued that the main factors that account for the differences between the US and European markets in agricultural biotechnology are the legislation surrounding the appropriability, regulation, and public acceptance of genetically modified crops. I will focus on the first of these factors as it is an important one affecting appropriability conditions. The other two factors will be discussed only briefly as the regulation and public acceptance literatures are immense and beyond the limits of this dissertation.

As mentioned in section 6.1.2, the US system allows for utility plants in agriculture, which opens up possibilities for patenting more than just plants but also living organisms. In Europe, however, the laws do not allow patenting for plant traits. As mentioned previously in this chapter, plant variety rights (PVR) on its own is considered to be a weaker IP regime for industry[42], reducing the appropriability conditions and possible profits, as the system allows for a researcher's exemption, meaning that follow-on developments on a variety can be conducted without the permission of the title holder (Schenkalaars Biotechnology Consultancy, 2005). A weaker protection regime may reduce the incentives of industry to conduct research.

Higher appropriability conditions could be a factor in explaining why there is more agricultural biotechnology activity in the US compared to Europe, where there is

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[42] Whether stronger IP regimes such as utility patents are good or not is a broader discussion than the possible profits it can bring; there are important discussions on public good and agriculture, which are beyond the scope of this dissertation.

less incentive for firms to invest in research[43]. Nevertheless, while the IP regime appears to be an important factor in explaining the differences between the USA and Europe, it should not be taken for granted as 'the' factor. As mentioned by Orsenigo et al. (2006), the rise in the number of patents in the USA following the Bayh-Dole Act was not necessarily an effect of the stronger IP regime but "a consequence of a wider set of technological opportunities" (p.415). In a similar vein, it is argued in this dissertation to a certain extent that, there are other factors effecting the appropriability conditions and the differences between the industry in the USA and Europe, such as investment in R&D. Orsenigo et al. (2006) add that while "stronger patent laws do indeed confer an advantage to innovators…they are certainly not enough to promote innovation in contexts where innovative capabilities are low or missing altogether" (p.415).

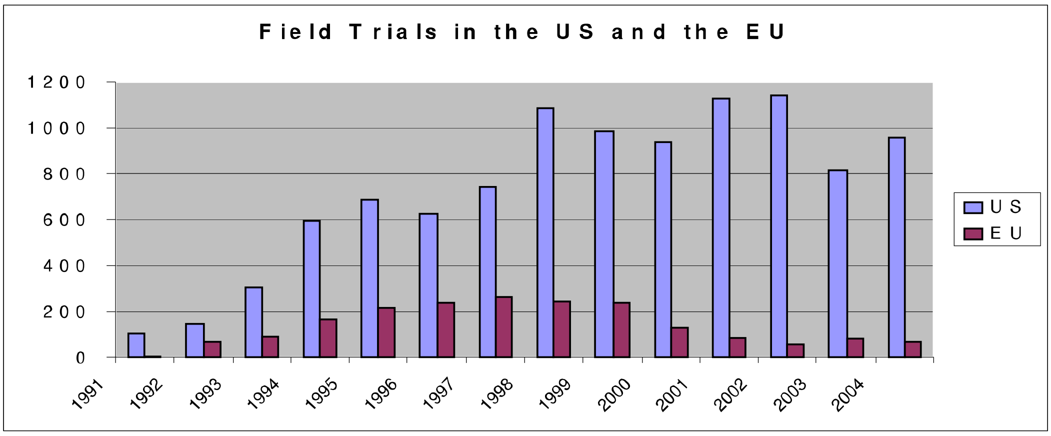
While it relates to the biotechnology sector in general, Critical I study (2006) with data from 2004 shows that although the number of biotechnology companies in the US and EU are about the same, the US industry employs approximately two times more people and spends three times more on R&D, two times more on venture capital and generates twice the revenue of EU industry. Although it is not possible to come to the conclusion that this is the case in agricultural biotechnology as well, it can be argued that the above-mentioned data imply a lack of investment in R&D Europe compared to that of the US, accounting for part of the differences. Indeed, it will be argued in the next chapter that especially in the case of the UK, certain innovative capabilities in the agricultural biotechnology sector have been diminishing over time, caused to a certain extent by the institutional context of the country.

Although it is difficult to find data to compare the performance of countries in agricultural biotechnology, as noted by Pray et al. (2005) the R&D expenditure data would be ideal to use for analysing research activity by private firms, but they report that there is no regular process of reporting biotechnology expenditure, and many private firms do not reveal such data in any detail (p.53). The authors argue

[43] Higher appropriability conditions can also be constraining for innovation by presenting difficulties for SME and PRO participation, which have to build on patented processed and organisms (Schenkalaars 2005:47). Cohen et al. (1995) point out that in cases where technology advances cumulatively, stronger appropriability regimes can be hampering (p.187). However, given that utility patents for plants are not granted in Europe, it can be considered as less of a problem.

that among the available data for agricultural biotechnology, field trial data is one of the easier to access and that it can be used as "a measure of research activity near the end of the research process" (p.53). Figure 6.2 shows the number of field trials in the EU and US, revealing the huge difference between the two. The European trials have decreased further from 1999 onwards when the market introduction of GM crops was put on a hold. While this ban is an issue of regulation rather than appropriability per se, the ban on GM crops is a disincentive for companies to invest in agricultural biotechnology research in the UK.

Figure 6.2: Field trials in the US and the EU



Source: Schenkelaars Biotechnology Consultancy (2005: 22).

In the early days of agricultural biotechnology, there was more activity in Europe compared to today in terms of active companies in the field. However, both the academic literature and the interviews indicated that with increased public opposition, stricter regulation and a corresponding decrease in market demand, many of these establishments and companies were shut down or moved elsewhere. Through MNEs several biotechnology-related activities were moved to the US and the rest of the activities were moved closer to the headquarters, which was also a cost-reduction strategy following the consolidation of the industry. An example to this was the Syngenta lab, which was located next to the John Innes Centre for a joint initiative until 2002 when the company pulled out of the initiative. An example from the Netherlands was a company called Mogen, started in the 1980s as a subsidiary of an American company that took up the patents coming from the group in Leiden University. However, according to one of the interviewees, the problem in this country was the opposition to the transgenic products, which eventually resulted in the company leaving the country:

> "…for a number of years nothing was possible here and that was very frustrating for many companies. A lot of them turned down a lot of activities and moved to other countries. In the end, this company was bought first by Zeneca and then by Novartis and moved to the US" (academic, Netherlands).

Reiss et al. (2007) point out that the problems raised by consumer resistance to GM food mainly affect the smaller seeds companies that lack subsidiaries in other countries where GM crops are grown. This is particularly relevant to this study where most of the companies interviewed are indeed SMEs without large global operations. Some of the companies have mentioned that they have research divisions in Spain and this is consistent with Reiss et al.'s (2007) argument considering Spain is one of the few countries in EU where GM maize is grown.

Malerba and Orsenigo (1997) argue that some features of technological environments are common to groups of industries and are "to some extent invariant" with respect to the institutional environment, although they add that country differences emerge in some technological classes (p.93). Based on the above discussions, I argue there that national – and to some extent supra-national - institutions do indeed matter considerably and can make the difference between 'make or break', as in the cases of USA compared with Europe. The authors also note that "the ability to generate and exploit opportunity conditions…is related to the level and range of university research, [and] the presence and effectiveness of science-industry bridging mechanisms..." among other factors (Malerba and Orsenigo 1997: 100). These factors are also related to the institutional environment, as will be demonstrated in the following chapter.

While Sectoral Systems of Innovation provides a useful tool in shedding light on important differences between sectors such agricultural biotechnology and medical biotechnology and also on how the institutional context affects the sectors, it is not enough to show the direct and indirect effects of institutional context. In the next chapter, I will extend the analysis to include the country-specific factors through a national system of innovation perspective and show how certain country-level policies affect the sector under consideration.

6.4 Chapter conclusions

In this chapter three concepts borrowed from the technological regimes and sectoral systems of innovation framework have been discussed specifically in relation to the agricultural biotechnology sector. It was shown that with the emergence of new techniques in agricultural biotechnology, new technological opportunities have arisen, which in turn have affected the agrochemical and seed industries. In relation to the appropriability conditions, it was shown that plant variety rights, as the dominant form of intellectual property protection in Europe, offers a lower chance for appropriability than in the US. Finally, we have discussed how the technological cumulativeness is affected by the existing knowledge sources.

Malerba and Orsenigo write that "the specific pattern of innovative activity of a sector can be explained as the outcome of different *technological regimes*" (1997: 84). The important part of this quote is that different sectors have different innovative activities. This means that firms will have varying links with universities based on the nature of the innovative activity, and therefore it can be assumed that the kind of intermediary that can provide benefits for facilitating links will vary across sectors too. One can argue then it is unlikely that a 'generic', sector-independent intermediary will be able to provide benefits for firms in all sectors, as it is unlikely that they are experienced enough for all sectors. Keeping this in mind, policies should take into consideration a variety of tools rather than 'one size fits all' instruments such as technology transfer offices or science parks.

We have seen that technological opportunities in agrochemicals are very much dependent on the developments in agricultural biotechnology, which takes place in corporate labs as well as in universities, and not so much through dedicated agricultural biotechnology firms in the case of Europe. Also considering that the sector is dominated by large firms, which have the resources and capabilities to build direct contacts with universities, it can be argued that there is unlikely to be a large role for any of the intermediary types described in Section 3.3. The interview data presented in the previous chapter confirm this assumption.

Technological appropriability within agricultural biotechnology is particularly limited in Europe due to the current IP regime. Therefore, transaction-based relations between university and industry are not likely to be very prominent, as has been confirmed by interviews. On the other hand, the sector is characterised by high technological cumulativeness, making retainment and accumulation of knowledge crucial to the advancement of the sector. It can be argued, therefore, that transformer and translator type intermediaries should be more prevalent than the transporter type.

Studies of sectors in terms of their knowledge and technology bases imply that each innovation system will place a different emphasis on a variety of university-industry interaction mechanisms (Brannenraedts et al. 2006). Based on the discussions of this chapter, it is also possible to suggest that certain configurations of technological regimes may be better suited for specific intermediary organisation types. I will briefly discuss these and try to schematise them in the following paragraphs.

It is the opinion of the author that *transporters* can offer advantages in high appropriability conditions such as medical biotechnology instead of low appropriability ones as in the case of agricultural biotechnology. It is difficult to pass a judgement regarding the opportunity and cumulativeness conditions based on the available data. For *hosts*, it would be difficult to make a judgement about what works or not based on the findings of this dissertation, although the academic literature suggests that they present advantages for smaller, high technology firms. As mentioned in chapter 6, small, innovative firm entry is a characteristic of a Schumpeter Mark I type environment, which is characterised by high opportunities, low appropriability and low cumulativeness. Given that universities are one of the sources for technological opportunities, more so for some industries than others, it can be expected that hosts will have a role in high opportunity conditions. The agricultural biotechnology sector, on the other hand, has the characteristics of Schumpeter Mark II with more established firms where there might be less of a role for hosts. A similar argument can be made for the case of *transformers* who mainly help out smaller firms. We have seen that *translators* such as public-sector research organisations are especially important for sectors with high cumulativeness, retaining a knowledge base. Finally, generators, such as the large programmes TTI-GG or CBSG, would present more advantages for a sector with high technological cumulativeness.

Table 6.2: An attempt to sketch the suitability of different intermediary types to technological regimes

	Opportunities	Appropriability	Cumulativeness
Transporter	X	High	X
Host	High	X	X
Transformer	High?	X	X
Translator	X	X	High
Generator	High	X	High

Source: Author's own

CHAPTER 7: INSTITUTIONAL DYNAMICS

The previous chapter looked into the agricultural biotechnology sector in the light of technological regimes and argued that certain characteristics of the sector can affect how university-industry relations take place. However, it was also noted these characteristics are not enough to explain the differences between two countries, and there are certain institutional factors that should be taken into consideration. Pavitt argued that the pressure in European countries for "more practical relevance in government-funded research" comes often from the governments who are "responsible for the accountability and the effectiveness of public expenditures" rather than business firms (2001: 770).

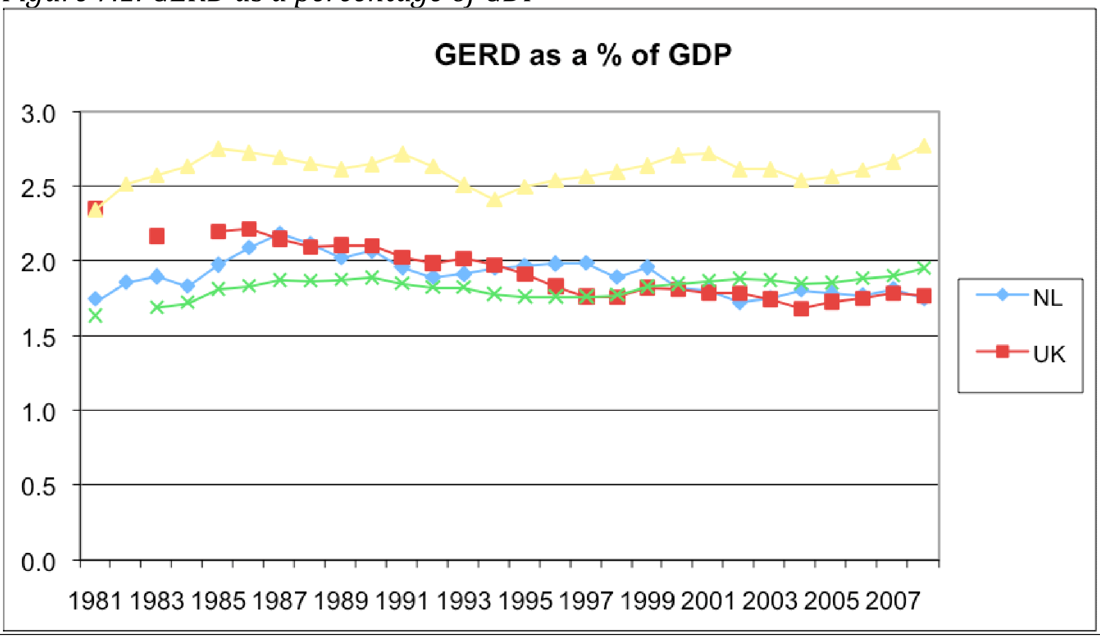
In this chapter the differences between agricultural biotechnology system in the Netherlands and the UK will be discussed, making use of the national systems of innovation framework. Using this framework, it will be shown that, in addition to sectoral factors, certain institutional characteristics at the national level affect the system. More importantly, it will be argued that the composition and interaction of the different elements of the system are crucial to understanding the differences between the countries.

Based on the empirical data presented in Chapter 5, some key elements of the system can be identified, which will be the focus of this chapter. Universities, public sector research organisations, and institutions in the form of relevant government policies are the elements that were highlighted in the interviews. The following sections will focus on the relevant policy developments in the two countries and their effects on the agricultural system, the composition of and changes to the research organisations, and current practices within the system. The last section will compare and contrast the two national systems in terms of institutional changes.

Before moving on to the comparison of the two systems, I will present some macro indicators regarding the R&D expenditures of the two countries, with the aim of reminding the readers why these two countries are comparable overall. It has been already argued in section 4.2 that the Netherlands and the UK make a worthwhile couple to be compared for observing the effects of different policies and institutional contexts on the same sector. Before focusing on the comparison between these two countries, it is valuable to see how they compare against the EU average and the US, in a similar vein to section 6.3.

To remind the reader once more, the proponents of the European Paradox argue that the level of science and technology in Europe is comparable to that of the US, yet there is a 'translation' problem from science and technology to innovation. The opponents of the so-called paradox argue otherwise, claiming the level of science and technology in the EU is lower than that of the US. This can be observed in Figure 7.1, which shows that the GERD as a percentage of GDP is considerably lower in the EU (both as an average and in individual countries) compared to the US. While this percentage has stayed more or less constant in the Netherlands, it has decreased by almost 25% in the UK between 1981 and 2008. The US on the other hand has increased its GERD by 21% in the same period. In addition to indicating the historical trends, Figure 7.1 also shows that regardless of the decline in the UK, the Netherlands and the UK have a similar expenditure ratio around 1.8%. This is an important indicator for assuring the comparability of the two countries as well.

Figure 7.1: GERD as a percentage of GDP

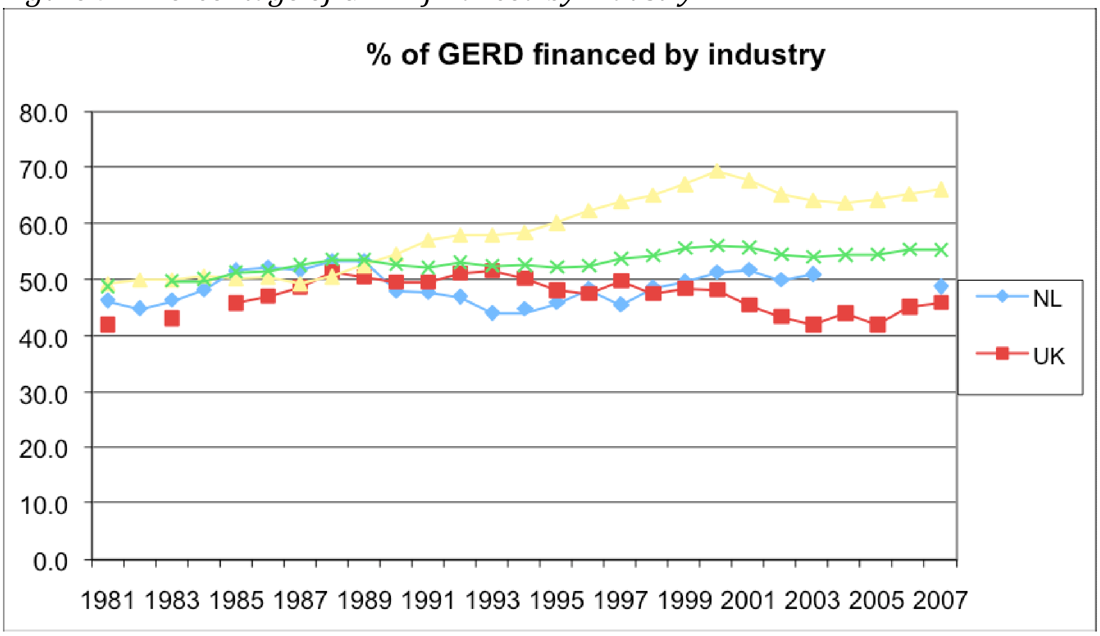


Source: OECD Science, Technology and R&D Statistics

One can argue that while the R&D expenditures of the two countries are comparable overall, there might be differences in the type of funders. Although there have been periods of differences, the Netherlands and the UK have similar compositions of GERD financed by industry and government. What differs is the historical trend.

Although varying through the period under consideration with ups and downs, the percentage of GERD financed by industry since the late 1980s to 2004 has declined in the UK by about 14% (Figure 7.2). In the Netherlands the industry financing decreased until 1993 and picked up again reaching around 51% by 2003. In both countries the current percentage of GERD financed by industry is close to 50%, accounting for about 0.8% of GDP. In the US, industry financed GERD as a percentage of GDP is around 1.8%, making up about 60-65% of GERD (OECD). These figures indicate that while the two countries are comparable with each other, the investment by industry in both countries is considerably lower than the US.

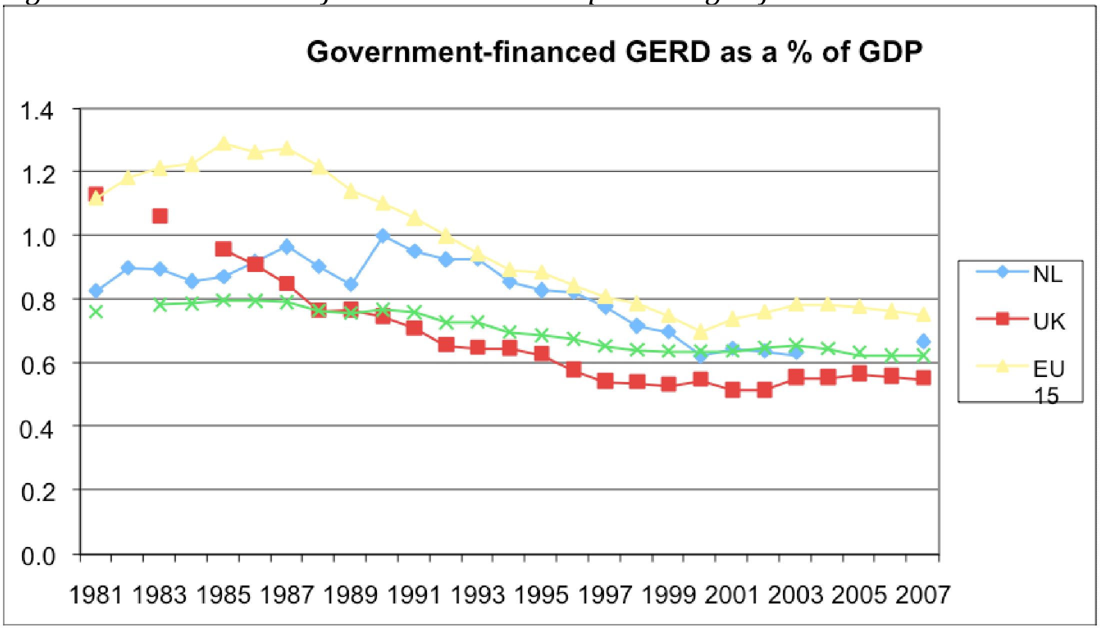
Figure 7.2: Percentage of GERD financed by industry.



Source: OECD Science, Technology and R&D Statistics

Regarding the percentage of GERD financed by government, the Netherlands, the UK and the US all range around 30-35% (Figure 7.3). All countries show the same historical trend of a declining share of government funding in GERD. However, as described in the above paragraphs, in the US industry financing is considerably higher, making up for the decline of funding from the government. In the case of Netherlands and the UK, there is much less industrial funding, which can create drawbacks for industry, as has been highlighted in chapter 5 as well.

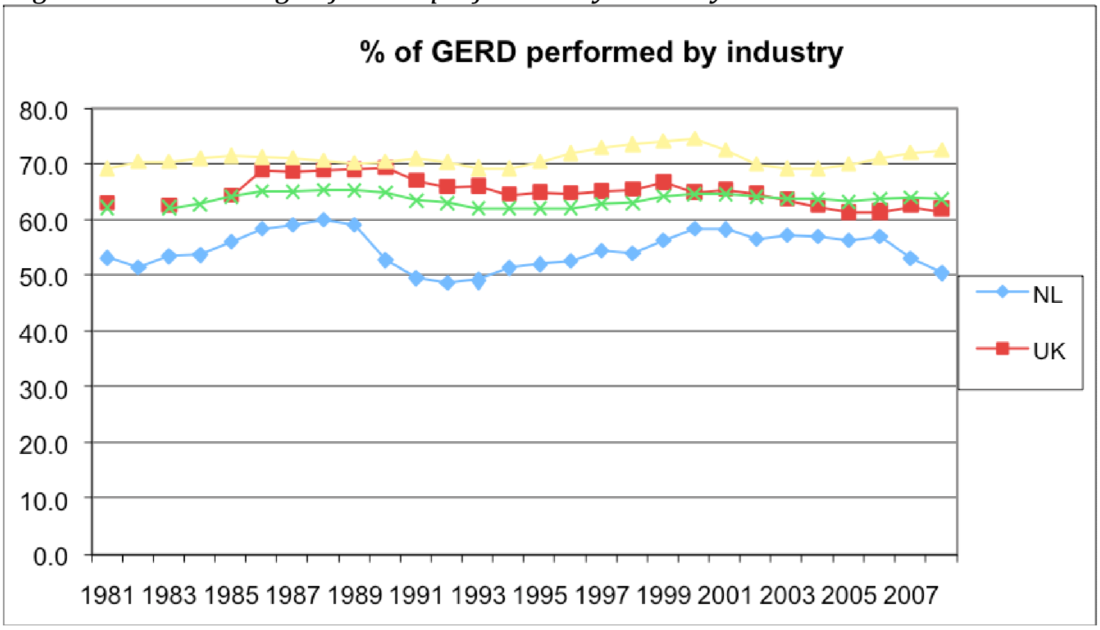
Figure 7.3: Government-financed GERD as a percentage of GDP



Source: OECD Science, Technology and R&D Statistics

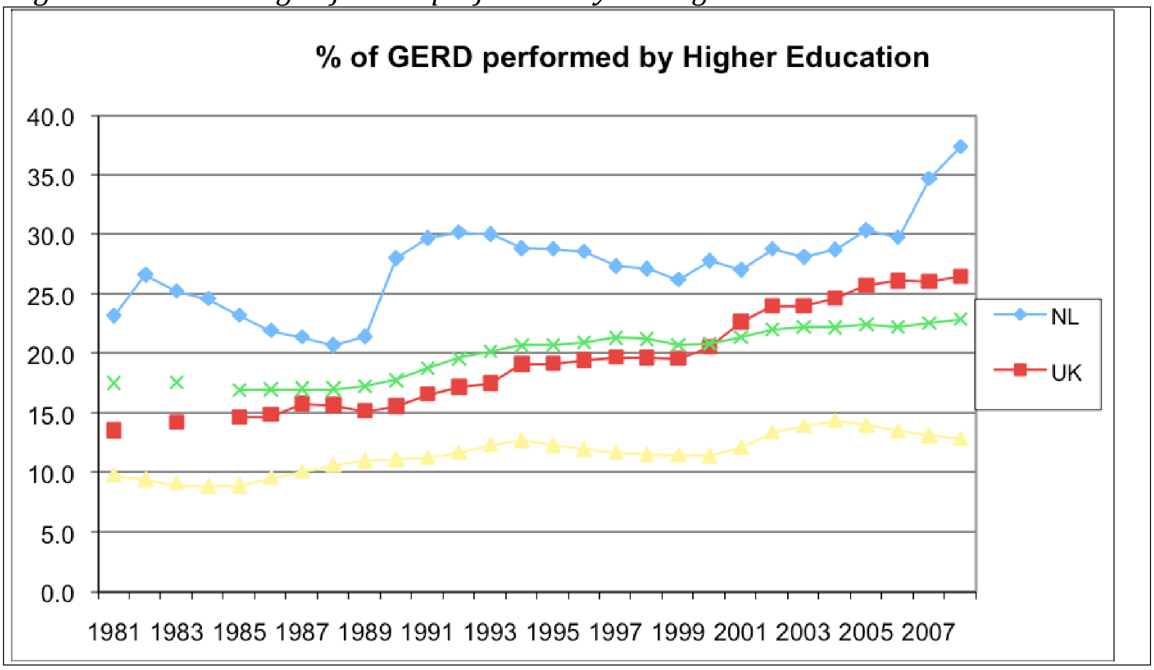
The trends with regard to the performers of R&D resemble those of funders. To begin with, the percentage of GERD performed by industry is higher in the US than the Netherlands and the UK (Figure 7.4). Comparing the Netherlands and the UK, this figure is higher in the UK (62% in 2003) than the Netherlands (51% in 2003). The percentage of GERD performed by the higher education sector has been increasing in both countries since the 1980s, with a relatively stable trend in the UK and a steeper increase in the Netherlands in the last years (Figure 7.5).

Figure 7.4: Percentage of GERD performed by industry



Source: OECD Science, Technology and R&D Statistics

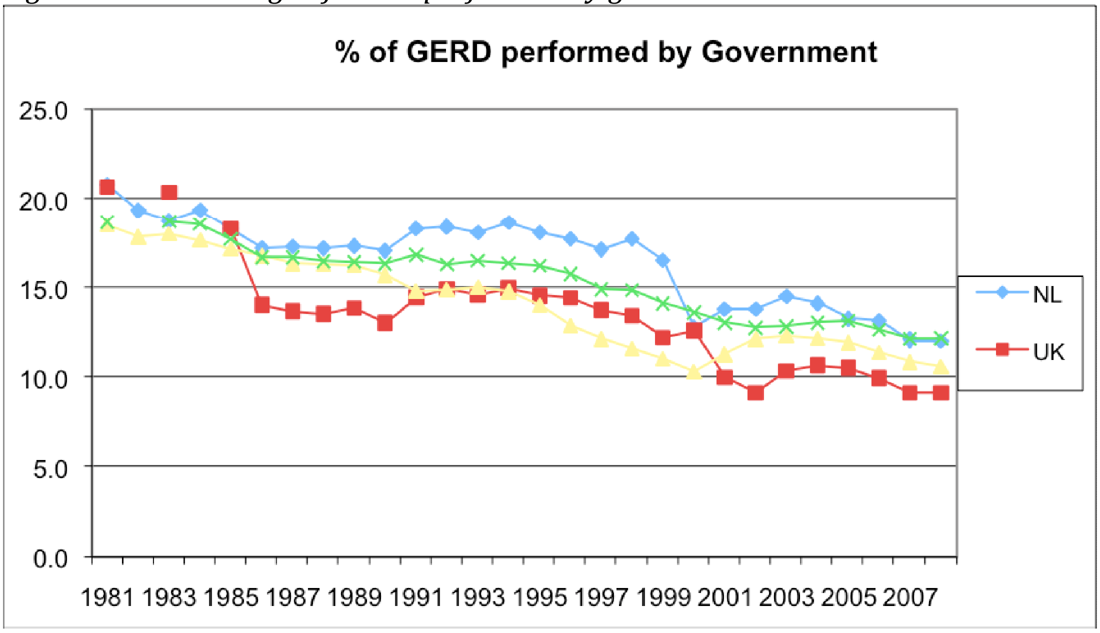
Figure 7.5: Percentage of GERD performed by the higher education sector



Source: OECD Science, Technology and R&D Statistics

In addition, in both countries the percentage of GERD performed by the government sector has decreased since the mid 1980s, with UK having a sharper decline (Figure 7.6). As will be discussed in the following section, this is consistent with the trend in agriculture, where there seems to have been a larger withdrawal of the government sector in the UK.

Figure 7.6: Percentage of GERD performed by government



Source: OECD

One of the most important differences between the two countries is the funding of R&D expenditure by the government. As will be discussed in the coming sections, although general university funds (GUF) have decreased in both countries, there is a significant difference in the amount of decrease. Table 7.1 shows that GUF as a % of total university funding has decreased by 40% in the UK, whereas this figure was around 15% in the Netherlands.

Table 7.1: Percentage of general university funds

	1985	1990	1995	2000	2003	2008	Change 1985-2008
GUF as % of total government funding for HE							
NL	92.6	94.1	92.6	93.3	86		-7.10%
UK	69.6	62.7	55.6	54	51.6	49.5	-28.90%
GUF as % of total HE funding							
NL	88.1	90.8	79.3	75.8	74.7		-15.20%
UK	57.2	46.1	37.7	35	34.8	34.3	-40%

Source: Calculated by the author based on OECD Research and Development statistics

The share of the agriculture, hunting and forestry industry's R&D expenditure as a percentage of BERD has decreased in both countries over time, albeit much more dramatically in the UK as shown in table 7.2.

Table 7.2: R&D Expenditure of the agriculture, forestry and hunting industry (figures in million PPP dollars in constant price)

	1987	2006	1987-2006 change
Total BERD			
NL	2720.6	6158	
UK	11463	22383	
Agriculture, Hunting and Forestry			
NL	49	62	
UK	74	137	
Agriculture, Hunting and Forestry as a % percentage of total BERD			
NL	1.8	1	-44%
UK	1.4	0.6	-133%

Source: OECD Research and Development Statistics

The above figures provide the context for the coming sections in several ways. Firstly, they show that the Netherlands and the UK have a similar macroeconomic environment. This is important as it makes it easier to observe how different institutional configurations work in similar economies. Secondly, the figures support the arguments opposing the so-called European Paradox, showing less investment in R&D and less industrial funding for R&D as well. This in turn makes one question whether policy tools focusing on the higher education are adequate enough without the presence of a strong industry, a question discussed in chapter 9.

7.1 Policies in the Netherlands

In this section I will look at those changes in Dutch science, technology and innovation policies, that I consider to have affected the current role of different intermediary organisations and institutions in the Netherlands. As most of the early policy documents in the Netherlands have been published in Dutch, accounts of other scholars will be used for the analysis of earlier policies.

The Innovation White Paper presented by the Netherlands Ministry of Science Policy in 1979 is considered to mark the beginning of a real innovation policy era in the country (Kern 2000)[44]. According to van der Steen et al. (2008), this was

[44] Scholars in the field of science, technology and innovation policy differentiate between different phases. Rothwell (1984) defines innovation policy as a fusion of science and technology policies with industrial policy (p.148). While science and technology policies were concerned with scientific education and funding of public sector research, industrial policies were mainly directed at the industrial restructuring, capital grants and R&D policies.

also the first official government document to raise the issue of university-industry knowledge transfer, taking a demand-side stance, resulting in the establishment of policy mechanisms such as the Innovation Oriented Research Program (IOP) and 'transferpunten'. The IOPs focused on biotechnology as well as other priority areas such as information technology, new materials and so on. The IOPs were "aimed at the development of fundamental technological and scientific knowledge and networking in strategic technology areas relevant to Dutch industry" (Kern 2000: 10) and were focused in the next 5-10 years. While the IOP is still running for different areas of science and technology, the 'transferpunten' were rather short lived.

According to van der Heide and van der Sijde, 'transferpunten' – or 'knowledge transfer points', as they are translated - were being established in each university at 1979 with the main purpose of matching "business people (especially SMEs) with academics, in order to improve the university's accessibility and to stimulate knowledge exchange" (p.1). They add that with the cut of funding for these organisations in 1989, they ceased to exist. It can be argued that transfer points can be considered as the first example of a top-down national policy on institutionalised technology transfer. Their dissolution following the funding cut may suggest that there was not an essential need for them in the first place. Of course, a counter-argument could be that they served a role during their existence but could not exist without funding. However, the lack of subsequent policy tools to establish similar organisations would suggest that they were not crucial.

It can be argued that both the IOP programme and the transferpunten model are based on a linear, unidirectional model of innovation focusing on supply-push. While the IOP programme focuses on conducting research relevant to industry, it is still far from a systemic understanding of innovation.

Another important consequence of the 1979 White Paper was the change in the funding structure of the TNO (Netherlands Organisation for Applied Scientific Research), in which government funding for TNO decreased and the organisation was expected to raise external funds. TNO is one of the largest public-sector research organisations in the Netherlands, working in applied research fields with the aim of "strengthening the innovative power of industry and government" (TNO

2010). As mentioned in Section 3.3, it is an example of a 'translator' type of intermediary, which has the capability to become involved in knowledge creation. The role of TNO in agriculture will be discussed in the next section, which also shows how this policy change has affected TNO's role in agriculture.

A report published by the external committee chaired by Wijffels in May 2004, reviewing the transfer functions of the TNO and the Large Technological Institutes recommended that the structure of the institutes should change towards an "entirely demand-driven system" and accordingly this was endorsed by the Dutch government (Ministry of Economics Affairs 2006: 70). This also entails a shift from direct financing of the institutes by the government to programme funding during the period 2007-2010. While it is too early to evaluate the results of such a shift, it resembles the customer-contractor principle of the Rothschild Report –that is discussed in section 7.4- and should be assessed carefully.

In 1993 the Ministry of Economic Affairs published a paper on "Industry policy for the nineties", which focused on the cluster concept with an emphasis on 'broker policies' (Kern 2000: 15). Smits and Kuhlmann write that this approach arose from the awareness of the mismatch between needs of industry and knowledge produced, and through networking the production and use of knowledge could be brought in line (2002: 23). The cluster concept focused on improving the links between companies, as well as between companies and research infrastructure and the organisation of regional groups. One of the results of this policy was the introduction of Technological Top Institutes (TTI) in different strategic fields, whereby large firms would cooperate with research groups from universities and public-sector research organisations. Green Genomics was one of these Technological Top Institutes, which will be discussed in the next section. The TTI model can be considered as an example of a policy tool based on a systemic understanding of innovation by linking up different actors in the system-university and industry in this case.

Kern writes that one of the concepts that gained emphasis within the cluster policy was the commercialisation of knowledge through innovative entrepreneurship where two areas of bottlenecks have previously been observed (2000: 17). One of these was felt to be the hesitation of venture capital firms towards investing in risky initiatives and the other was the lack of entrepreneurship, particularly within the academic research sector. The policies directed towards solving these bottlenecks involved the use of intermediary tools as well. Some of the initiatives taken by the government were the 'Technostarter Funds' and Twinning directed at capital issues, as well as the biotechnology incubators that would provide appropriate physical conditions for start-ups, and the development of these would be realised through the cooperation of government, industry and research organisations (ibid.).

In 1995 three ministries[45] presented the policy paper entitled "Knowledge in Action", in which the emphasis was on cooperation between research institutes and industry in order to strengthen the Dutch knowledge intensity (Kern 2000: 14). Kern argues that this was a turning point in the Netherlands towards an innovation policy based on an understanding of innovation as an interactive process (2000: 15).

The 1999 report by the Advisory Council for Science and Technology Policy (AWT) criticised the previous government efforts in three areas for falling short of an 'innovation system' view and made three suggestions: (1) stimulation of an innovation culture and climate, (2) clear missions and tasks for the (semi-) public research institutes, and (3) more emphasis on fundamental research activities (Kern 2000: 19). Particularly the second and third types of changes have been voiced during the interviews in the Netherlands, regardless of whether they were linked to the ATW report or not. Dutch innovation policies have created focus areas of research in the following years, and this streamlining has been observed in the case of Wageningen University as well, where priority areas were established. Regarding the emphasis on fundamental research, interviewees from both industry and university in the agricultural biotechnology sector said that there has been a shift towards more fundamental research in the sector, as mentioned in chapter 5.

The Innovation Platform (Innovatieplatform) was established in 2002 by the government as an advisory board, with the objective "to propose strategic plans to

[45] The Ministry of Economic Affairs, Ministry of Education, Culture and Science, and Ministry of Agriculture, Nature Management and Fisheries.

reinforce the Dutch knowledge economy and to boost innovation by stimulating business enterprises and organisations in the public knowledge infrastructure to work closely together" (van Giessel et al. 2007). It would not be wrong to suggest that this was the first time there had been such a body with members from the Cabinet, the Ministry of Education, Culture and Science, the Ministry of Economic Affairs, industry and research institutes. While similar bodies exist in the UK too, such as the Technology Strategy Board, the Innovation Platform seems to be different in the sense of being a 'platform' and not a government body, yet having government representatives involved. One can argue that this is an example of the negotiation-based culture of the Netherlands[46].

In 2003 the Dutch government launched an Innovation White Paper entitled "Innovation Letter: Action for Innovation: Raising the Dutch knowledge economy to a leading position in Europe", which introduced the idea of "focus and mass" (van Giessel et al. 2007: 125). The focus areas for innovation policy defined in this documents include the strengthening of the climate for innovation, creating a dynamic climate for companies, and focusing on strategic areas given the limited resources of the country (ibid). The first of these two areas resemble the first two bottlenecks identified by AWT and described in the above paragraphs. It can also be seen that this represented a shift towards a more explicit agreement on making strategic choices for the fields to be supported instead of improving the fundamental research base in general.

One of the government documents published, following the Innovation Letter, was entitled "Strong basis for delivering top performance" in May 2005, directed at entrepreneurs. This document put forward packages for entrepreneurs such as the innovation vouchers, and aimed at strengthening the interface between academia, industry and government through collaborative programmes. As stated by the Ministry of Economic Affairs "the Dutch government is backing winners instead of picking winners itself" (EZ, 2006). One can see that there is a difference again between the Netherlands and the UK policies whereby the Dutch policies focus on demand-side tools, whereas the UK policies aim to strengthen the demand side

[46] Smits and Kuhlmann refer to a strong consensus tradition in policy making in the Netherlands, also known as the Polder Model (2002: 19).

through supply-push tools.

Despite the policies directed at increasing university-industry collaboration, commercialisation has entered the Dutch policy scene rather later compared to the UK. Van der Steen et al. (2008) write that 'valorisation'[47] was mentioned for the first time in the "Higher Education and Research Plan" (HOOP) of 2004, but this took a rather monolithic view of knowledge exchange without paying attention to the diversity of knowledge transfer channels and disciplines. Van Giessel et al. write that the European Paradox idea is the starting point for valorisation activities, arguing that the paradox is observed in the Netherlands too, with excellent research but inadequate interactions between public and private actors and not enough commercialisation of research (2007: 134). As an explanation for this situation, they argue that companies disregard university knowledge and rely heavily on specific sector partners. This argument is also supported by an OECD report that highlights the excellence of research in contrast with problems in translation, an explanation that is linked to the decline in the innovative performance of the Netherlands. (OECD 2005: 147). While reliance of companies on other firms is not a phenomenon unique to the Netherlands, it should also be considered whether this is a weakness at all times. It has already been shown by scholars such as Pavitt (1984) that different sectors have differing reliance on science. Therefore before considering weak interactions between university and industry as a problem, one should look at the nature of the sectoral characteristics.

7.2 The agricultural research system in the Netherlands

For a long time the Dutch agricultural system was based on a so-called triptych of education-research-extension (OVO: Onderwijs, Onderzoek, Ondernemerschap), which is argued by some authors to be one of the reasons why the Netherlands is so strong in agriculture (Kamphuis 2005; Dons and Bino 2008). As Poppe (2008) points out, this was based on the classical linear model of innovation starting with fundamental science in universities, applied science in the public research organisations, which is then transferred through the extension services to farmers for the application (p.12). This system has been restructured considerably in the

[47] As defined by the Netherlands Genomics Initiative, valorisation refers to "the flow of new knowledge to users with a view to applying this knowledge in products, processes and services" (NGI 2010).

last twenty years in response to general science, technology and innovation (STI) policies in the Netherlands. In this section I will look mainly at the research and education part of this triptych, as these elements appear to be at the forefront of my interviews and other sources. The extension system will not be covered in this dissertation, mainly because it is related more to industry-user (farmer) relations than to university-industry relations. Furthermore, given the limits of the dissertation I have made a pragmatic decision to leave the extension system out, prioritising the research aspect. However, the reader can refer to Klerx & Leeuwis (2009) for changes in the extension services as a form intermediary organisation in the Netherlands.

In addition to industry, the main actors of the Dutch research system are the higher education sector and government research institutes. It was shown at the introduction of this chapter that the share of the higher education sector among the R&D performers is increasing. In the Netherlands, universities are funded through three main streams and the relative proportion of different streams has been changing over time. The first flow of funds for universities is from the OCW and is the largest source of funding, making up approximately 60% of the total funding. The second flow of funds, which are allocated by NWO, KNAW and STW on a competitive basis, account for 10%. Finally universities receive around 30% of their income through indirect governmental sources, foundations and industry (ERAWATCH 2010: 72). While the share of government base funding for universities remain relatively large, in 2007 the government decided to transfer €100m of this stream to competitive funding via NWO (ERAWATCH 2010:61). The OCW figures regarding the trends in flow of funds, indicated by the percentage of academic research staff funded by different streams[48], show that the second flow of funds have been gaining importance in the last two decades.

[48] Unlike in the higher education statistics in the UK, the shares of different streams of funding are not readily available in the Netherlands.

Table 7.3: Trends in the share of first, second and third flow of funds for universities in the Netherlands

	1990	1995	2000	2005	2006
Academic research staff (total) (FTEs)	13935	14545	15000	17353	17397
Academic research staff 1st flow of funds (%)	58.0	56.4	52.5	48.4	48.2
Academic research staff 2nd flow of funds (%)	15.3	16.8	20.3	24.1	23.8
Academic research staff 3rd flow of funds (%)	26.8	26.9	27.1	27.5	28.0

Source: OCW-The science system in the Netherlands (2008)

Government funding for Dutch universities is quite liberal in the sense that in addition to student numbers, it is very much based on self-evaluations, rather than a strict performance-related system, although there are preparations for the introduction of such as system (ERAWATCH 2010). This is an important point, especially in contrast to the UK system where university funding for research is based on scientific excellence, as will be discussed in the following sections. While academic interviewees from the UK brought up the conflicts arising between commercialisation activities and research excellence, it was not brought up by the Dutch academics in interviews.

As mentioned in section 2.2.2, a common argument within the literature regarding universities and university-industry relationships is that decreasing general government funding for universities has pushed universities to search for external funding (Senker 1998). This argument was brought up in the Dutch case as well, as mentioned by the following interviewee from industry:

> "Times have changed from 20 years ago when there was no interest in working together with industry and that was assumed to be unethical. What has happened is all universities and university researchers have scarcity of money. They have a lack of money for research. Everyone is eager to have contracts as long as they get money and people to do research" (academic, NL).

A sectoral association representative was also of the opinion that because of the decreasing government funding, universities are looking for contract research and they tend to direct their research towards where they can get contracts from, leaving some areas under-researched (Other , NL).

While there are a number of universities with units working on plant sciences, Netherlands has a dedicated agricultural university in Wageningen. Wageningen University is different from the other universities not only because of its concentration on agriculture but also because it has been funded by the Ministry of Agriculture, Nature Management and Fisheries (LNV) instead of the Ministry of Education, Culture and Science. Within its new structure consisting of the university and applied research centres, there are five science groups, of which the Plant Sciences Group is the relevant one for this dissertation. The Plant Sciences Group is composed of the Plant Sciences Department of Wageningen University, Plant Research International (PRI) of the DLO institutes and the Applied Plant Research (PPO) centre.

According to Dons and Bino, this re-organisation was partly driven by a transformation from a 'knowledge-driven' to a 'demand-driven' research, and partly by the need for more multidisciplinary research (2008: 131). However, it can also be argued that the change was also caused by the attempt to cut government costs. Nevertheless, as the authors argue, it can be said that this represented a move away from a linear model to a more interactive one in which the different parties work more closely with each other.

The restructuring of the public agricultural system had a number of consequences as identified by the interviews, which are discussed in the following paragraphs. One of the most important consequences was the reshaping of the division of labour in the knowledge spectrum. In the original triptych model, there was a linear division where universities covered the fundamental science, DLO institutes covered the applied science, the experimental research services covered the development and finally the end-results were transferred to the farmer through the extension services.

Two of the industry interviewees mentioned that following the merger of the DLO institutes with Wageningen University, institutes that had previously conducted applied work have moved closer to universities in the type of work they conduct (industry, NL-B15, B4). One interviewee argued that this had consequently resulted in an expansion of industry research to cover the applied research area that was previously covered by the DLO institutes.

An institute member confirmed the above argument about DLO institutes moving closer to the fundamental research side as well. He explained that the knowledge explosion in biology has driven their research more towards fundamental issues. He added that the big companies in the Netherlands favour their work on this more fundamental area, as this is where new developments will mostly come from. As mentioned in sections 2.2.1 and 5.1 larger companies are mainly interested in tapping into fundamental research in public sector organisations, whereas SMEs are mainly interested in more applied knowledge. Considering that DLOs traditionally conducted applied research and that the agriculture sector was dominated by SMEs, the argument of a gap in the knowledge spectrum, with possible detrimental effects for the SME sector, makes sense. The interviewee also said the problem lies more with smaller companies and fields outside vegetables and horticulture - such as ornamentals[49] - where companies face difficulties because they do not have large research departments in which they can carry out more applied research.

The claimed move of DLO institutes towards the more fundamental side can also be confirmed by the number of interviewees (industry, NL- B8, B9, B15) who commented that they do not see much difference now between the work of universities and institutes. However, there were still some interviewees who expressed the view that they prefer the Applied Plant Research station (PPO) for practical studies that are closer to the field.

Another consequence of the restructuring of DLO institutes was in terms of the effect on the supply of trained personnel with practical skills. One interviewee said it is now hard to find people with these skills and the supply is more on the molecular biology side. Although the vocational schools (hogerschool) have the role of educating people with practical skills, this is usually enough only for the

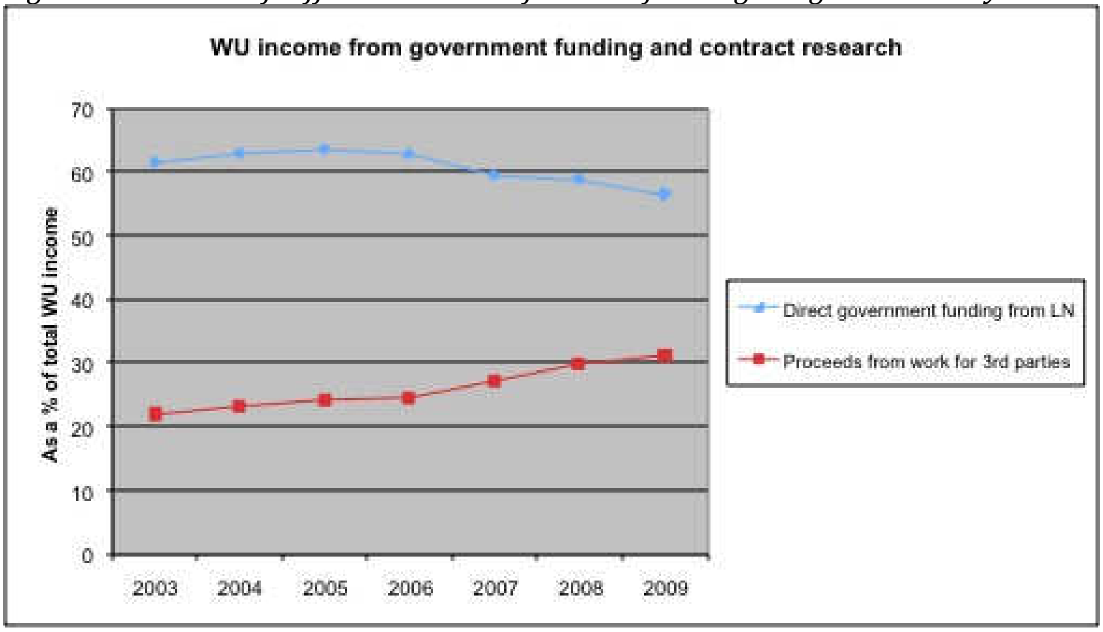
[49] Ornamentals refer mainly to the flowers sector.

technician level and not beyond. Valk (2003) shows that that total number of agricultural institutes (ranging from vocational schools and practical training centres to universities) have decreased from 206 in 1985 to 20 in 2003, supporting the case that opportunities for trained personnel might have been decreasing.

While some industry interviewees expressed concern about the merger of DLO institutes with Wageningen University, there might also be certain long-term benefits for industry. The Plant Science Group is led by two scientists, one from the university side and the other from the institute side, with employees from both sides, and according to an institute researcher they conduct "integrated approaches to plant breeding" in increasing collaboration with breeding companies. This may be an organisational structure in which a more seamless flow from basic research to application can take place.

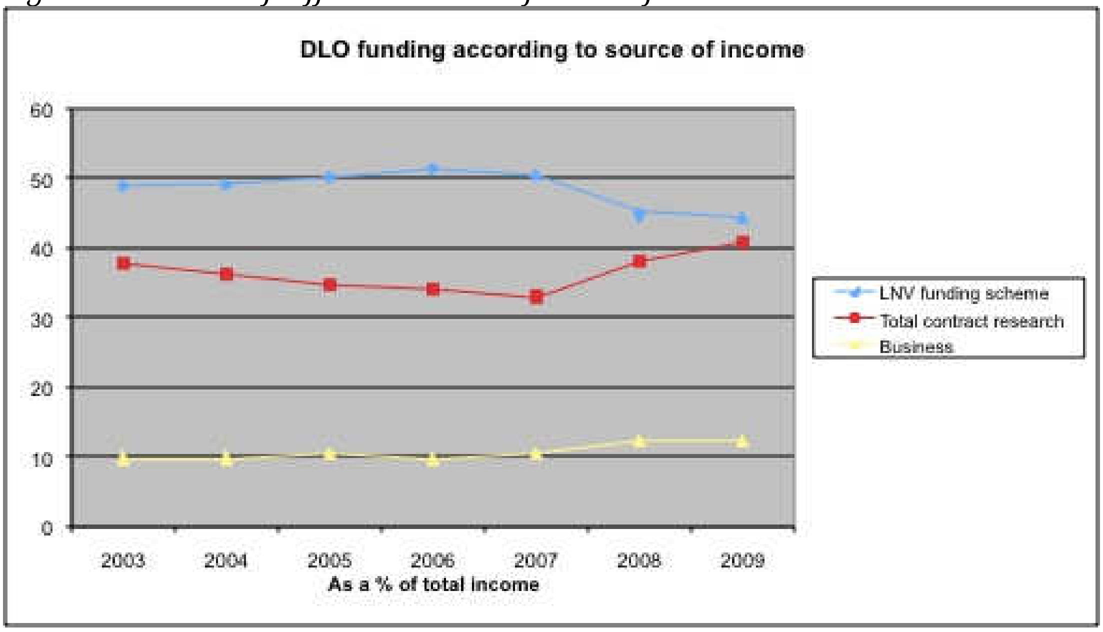
In addition to the restructuring, another factor that affects the relationship between the institutes and industry is the way institutes are funded. Previously funded almost entirely by the Ministry of Agriculture (LNV), the institutes now receive about 45% of their income from the government and the rest of their income is from external sources. Their core funding is in the form of competitive grants, which they get in four-year periods. The funding from LNV for the DLO institutes have experienced a cut as well showing a 19% decrease between 1978 and 1995 (Roseboom and Rutten 1998: 1120). The annual reports of WUR and DLO institutes also confirm that there is a decline in the share of funding from LNV and an increase in the share of income derived from contract research and work for 3rd parties (Figure 7.7 and 7.8) According to a DLO interviewee, the funds that are allocated by the government are determined according to the proposals brought forward by the DLO institutes, which should address the strategic priorities of the ministry. A similar remark is made by Cornet and van de Ven, who write that the research programmes commissioned by the LNV are increasingly geared towards the needs of the Ministry (2004:22).

Figure 7.7: Shares of different sources of income for Wagening en University



Source: Constructed by the author from the annual reports of Wageningen UR

Figure 7.8: Shares of different sources of income for DLO institutes



Source: Constructed by the author from the annual reports of Wageningen UR

In addition to the DLOs, there was in the past a small role for the TNO in agriculture, which has now disappeared. The TNO institute had an Applied Plant Sciences department located in Leiden University, working on transgenic plants. Between 1996 and 1999 the TNO department had 42 publications of which 26 were in ISI journals, not far behind the publishing levels of plant sciences department in the universities. To give an example, Table 7.4 shows that out of the 8 articles published in 1999 in the Plant Cell journal, which has the second highest impact factor in the field, the TNO article is in the middle in terms of citation numbers. Based on similar simple comparisons, it can be argued that while TNO department was not leading, it was certainly an active organisation.

Table 7.4: Share of different plant science organisations' publications in the Plant Cell Journal in 1999

PLANT CELL

1999: 8 articles with the address from the Netherlands

id	**citation #**	**Affiliation**
1	81	Utrecht/ Wageningen
2	56	Wageningen
3	68	Amsterdam
4	41	Wageningen
5	12	Amsterdam
6	26	Nijmegen
7	56	Wageningen
8	*40*	*TNO*

Source: Author's own elaboration based on ISI Web of Science

One of the university interviewees indicated that TNO saw an opportunity in plant biotech and started a group in Leiden, mainly carrying out contract research for the existing industry contracts and that they were quite successful at it. This can also be seen in Table 7.4 above, where the citations of the TNO publications are ranking in the middle. However, with increasing public opposition to agricultural biotechnology, the group was decreased in size and it eventually was spun off from TNO into a company called Fytagoras in 2007. According a TNO interviewee, the vulnerability of the Applied Plant Sciences department was also due to insufficient critical mass and the lack of a market for the resulting technology.

7.3 Current system solutions in the Netherlands

Three organisations or institutions that are currently active in the Netherlands agricultural biotechnology system are worth analysing in more detail in particular because they were mentioned as successful institutional arrangements during the interviews. Two of these, the Centre for Biosystems Genomics (CBSG) and the Technological Top Institute - Green Genetics (TTI-GG) can be considered as successful examples not only because they have large participation from industry and research organisations, but also because they are considered to be beneficial by interviewees for various reasons such as income generation, knowledge generation and sharing, and networks[50]. Keygene, on the other hand, is almost unique not only because it is one of the rare dedicated agricultural biotechnology firms, but also because it is funded by industry and works in strategic fields as well.

It was already mentioned in Section 5.6 that Keygene was founded by several Dutch seed companies to help them innovate by conducting strategic research, when agricultural biotechnology started to prove relevant to the seed sector, and research was too expensive and risky for one company to engage in. On the other hand, one can argue that the continued presence and success of Keygene can be associated with its particular role in the knowledge spectrum. To be more precise, Keygene mainly conducts strategic and applied research, an area that is associated with the public-sector research organisations in the innovation system, such as the DLO institutes and TNO in the case of Netherlands. If there is indeed a gap in the continuum from fundamental research to the applied side, as mentioned by some interviewees, Keygene's presence can be explained by its capabilities in the part of the knowledge spectrum in agriculture that would otherwise be rather weak.

The success of Keygene also lies in the fact that there is a constant demand for taking up the results of their research. These include the companies from the industry that are the stakeholders of Keygene as well as other clients. Industry members often mentioned that university research is too broad to be taken directly to application and there needs to be further developments before an idea can be turned into a product. One of the reasons for this is argued to be the disconnection of university research from industry needs. On the other hand, in the case of Keygene, there is a continuous relation between them and the stakeholder – seed companies - that from early on can give feedback on the applicability of research results to the market and can serve as an outlet for testing ideas.

Another reason for the success of Keygene is the importance of long-term collaborations for technological cumulativeness, which is especially important in

[50] Out of 26 interviews in the Netherlands, 6 mentioned benefits associated with CBSG and 4 with TTI-GG. The remainder have not expressed any negative opinions.

the plant-breeding sector. With respect to their collaboration with Keygene, an industry interviewee mentioned that one of the benefits or working with Keygene was that Keygene know the crops they are working on and also their problems. In this sense, one would expect longer-term programmes to be more beneficial for university-industry relations in the agricultural biotechnology sector.

Technological Top Institute - Green Genetics (TTI-GG) is an initiative from companies mainly in the plant breeding industry, which was started in 2007. It was founded with the aim of providing industry with strategic knowledge in the fields of plant genetics, plant physiology and plant pathology for the horticultural, floricultural and agricultural crops (Dons and Bino, 2008). TTI-GG is jointly funded by the government, industry and research organisations. The research topics are "demand-driven and are prioritised by the industrial partners" (Dons and Bino 2008: 136). The business plan of TTI-GG states that the idea was "the result of an open discussion between industry and academia…on how the "knowledge gap" between academic research and practical application can be bridged" (TTI-GG 2005: 2).

According to one interviewee involved in the management of TTI-GG, the project proposals are initiated by companies, who then approach research groups in universities and institutes with a view to collaboration, rather than the other way around. He said that through such an approach they want to initiate new research because, if the focus is too much on institutes, "at the end of the day you have 20 universities sitting together and doing the research they always did" (industry, Netherlands).

The structure of TTI-GG, where industry has a very strong influence and involvement, may be one reason for its success. As in the case of Keygene, industry involvement will ensure that the research is directed towards the needs of the industry even though it is of a strategic nature. The involvement of industry with academics in the research process also seems to have benefits for generation of IP and products that are of use to the industry:

> "...it's an umbrella organisation...under the umbrella there's direct interaction. If you're talking about IP etc, you have people who know that

> whether or not results can be used or applied so they don't need an intermediate. If you're talking about complete fundamental research, with low relation with industry there you may need, at least within the research organisations, people who can do the valorisation of knowledge, who can help them with IPR". (academic, NL)

In Chapter 5 it was shown that industry is most interested in gaining more fundamental and strategic knowledge from research organisations than applied knowledge. The financial commitment of industry in the TTI-GG initiative would seem to support this argument.

The Centre for BioSystems Genomics (CBSG) is a large public-private partnership in the Netherlands, which was founded in 2003 as part of the Netherlands Genomics Initiative. Initially funded for five years, its funding has been extended for another five years until 2012 into the light of its success. The programme focuses on tomatoes and potatoes and is supported by the presence of a strong potato industry in the Netherlands. While there is strong industry participation, the lead players in CBSG are the research organisations.

CBSG addresses a number of issues that are problematic in the agricultural sector in the Netherlands. The long-term funding is in accordance with the need of plant breeding; the programme provides funding for the training of students; and the collaboration between the research base and industry allows for the translation of fundamental knowledge into crops. The CBSG website specifically states that "it recognises that it has a significant responsibility to train the scientists of the future to meet the needs of both academia and industry"[51]. It continues to explain that

> "By providing PhD positions for recent graduates and by establishing state of the art genomics technology platforms that are available for young postdocs to extend their expertise, CBSG ensures that these budding future captains of industry develop the best possible scientific background to meet the future needs of science and commerce. Also, through our direct interaction with commercial companies, CBSG scientists get a first hand view of not just academic but also applied research."

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[51] http://www.cbsg.nl/education.aspx (accessed 19.03.2012)

An intermediary organisation representative mentioned that under the CBSG there is dedicated funding for valorisation:

> "...part of the money goes to phase number II and part of the money is meant for technology transfer….technology transfer is an obligatory part of such a business plan. That means you have to give serious attention and you're expected to show during the programs that you have activities on technology transfer and how you organise it."

While the existence of funding to support valorisation activities, the programme also has valorisation targets that may have negative consequences if these targets do not occur as a natural result outcome of the research[52].

Bunthof et al. (2005) compare the national plant genomics programmes across European countries, also looking at the funders of these programmes. As can be seen in figure 7.9 there is a striking difference between the Netherlands and the UK in that while there is a variety of funders in the Netherlands, including a considerable share from industry, the programmes in the UK[53] are entirely funded by the government (at least at the time the report was published). It can be argued that this further accentuates the difference between the strength of breeding industries in the Netherlands and the UK.

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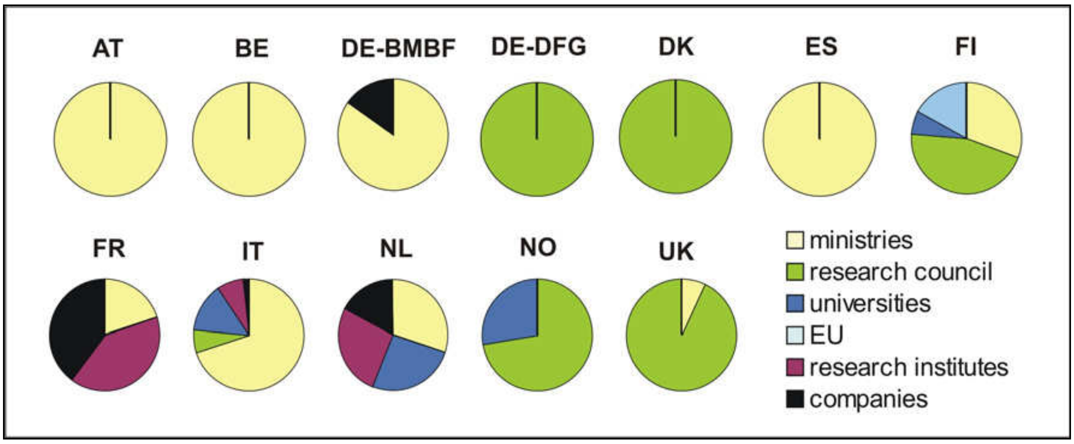
[52] Academic literature has drawn attention to the possible unintended consequences of policies focusing on commercialization activities (Geuna 2006; Poyago-Theotky 2002).

[53] These programmes, as listed in the report, are UK GARNet and GARNet 2, UK Brassica, UK Cereals and Arabidopsis stock centre as well as the funding of research component by BBSRC, DEFRA, SEERAD, NERC and Gatsby (Bunthof et al. 2005: 18, Table 2.2).

Figure 7.9: Budget sources of national plant genomics programmes



Source: Bunthof et al. (2005: 10, figure 2.3)

Findings of this study suggest that the Dutch industry is more actively involved in the design of large collaborative programmes. Bunthof et al.'s study (2005) supports this suggestion, where they demonstrate that while the industry in the Netherlands is involved with the national programmes, the UK industry seems to be absent, which can be seen in figure 7.10

Figure 7.10: Stakeholder's influence on the initiation and creation of the national programmes

		FR	DE BMBF	NO	DK	ES	NL	UK	AT	DE DFG	FI	IT	BE (F)	Sum
1.	Scientists	x	x	x		x	x	x	x	x	x		x	10
2.	Ministry	x	x	x	x	x			x			x		7
3.	Research council			x	x			x		x	x	x		6
4.	Experts from abroad		x	x		x		x						4
5.	Plant breeding industry	x	x				x							3
6.	Other industry	x					x							2
7.	Management agency				x									1
8.	NGOs	x												1
	Sum	5	4	4	3	3	3	3	2	2	2	2	1	34

Source: Bunthof et al. (2005: 22)

7.4 Policies in UK

Although there are important events from the early 20th century that shaped the current innovation system in the UK, I will focus on the changes since the 1970s – starting with the Rothschild Report - in terms of looking at the general science, technology and innovation policies in the UK.

The Rothschild Report was one of the most important documents of UK research policy in the last century in terms of its effect on the restructuring of research organisations, and agriculture in particular. Previously a chairman of the Agricultural Research Council, Lord Rothschild in his 1971 report introduced 'the customer-contractor principle' for applied research into UK research policy. According to this principle, "the customer says what he wants; the contractor does it (if he can); and the customer pays" (Rothschild 1971: 3). The 'customer' refers to government departments whereas the 'contractor' refers to research councils and other government research organisations.

This report affected the former Agricultural Research Council (ARC) and the former Ministry of Agriculture, Fisheries and Food (MAFF) in particular because of the extent of the funding changes proposed for them. The report criticised the ARC for being too far removed from the needs of its clients and recommended that the budget of the Research Councils for applied research should be transferred to the relevant customer departments. For the ARC the recommended amount corresponded to approximately 70% of the budget, which was previously paid by the Department of Education and Science. As Thirtle et al. (1997) wrote, this can be considered as a fundamental shift from the 'Haldane Principle'[54], which had been an important pillar of the UK science and technology policies since 1918.

While there has not been any substantial government documents regarding innovation until the early 1990s, the policies of the Conservative government of the 1980s can be observed in several documents. The 1979 Manifesto of the Conservative Party signals the path for government withdrawal from near-market research. Under the heading "Better Value for Money", the document says that they shall "reduce government intervention in industry and particularly that of the National Enterprise Board". This change can be observed in the percentage of BERD financed by government, which decreased from 23% in 1986 to 7% in 2008, representing a 70% decline (based on OECD statistics).

In the 1980s the removal of government funding from near-market research affected the agriculture sector as well, as discussed in the following section, but

[54] The Haldane Principle refers to the Haldane Report of 1918, which recommended that science should not be under the direct control of government departments, and which led the formation of the Research Councils.

there were no policy documents at the national level until the 1990s that significantly affected the sector. In 1993, the government published its White Paper "Realising Our Potential. A Strategy for Science, Technology and Engineering". The paper recommended that "privatisation is a realistic prospect" for a number of government research establishments (HMSO 1993) and this affected several of the research organisations working in the agricultural sector, such as the National Seed Development Organisation (NSDO) and part of the Plant Breeding Institute (PBI), which were privatised. Dresner (2002) writes that "the rationale for the new structure was about making the research community more responsive to the needs of the country, particularly in terms of economic competitiveness." (p.171). The paper emphasised the notion of the "creation of wealth" through a close interaction of research establishments and industry, and gave universities a key role in this process.

Resembling the report of the AWT in the Netherlands around the same time, a report of the National Academies Policy Advisory Group[55] (1995) raised concerns about extracting practical benefits from university research at the cost of funding for basic research. This stated that basic research is crucial for commercial success and a decline in its support could have long-term consequences (p.34). While several of my interviewees considered basic plant science in the UK to be very good (industry, NL- B4, B21), there were concerns at the lack of strategic level knowledge.

1993 White Paper has affected the plant breeding sector through the withdrawal of government funding from near-market research and the privatisation of a number of public research organisations including the agricultural sector. While the support for basic research is crucial, as mentioned by the above report, it is also important to have research in the more strategic and applied part of the spectrum in order to translate this knowledge. Similar to the DLO institutes in the Netherlands, there were several public-sector research organisations in the UK, such as the NSDO and PBI conducting near-market research. Withdrawal of government funding for this kind of research combined with a declining industry

[55] NAPAG comprises the Royal Society, the Royal Academy of Engineering, the British Academy and the Conference of Medical Royal Colleges.

not able to fund research has had negative affects on the British agricultural system. As opposed to the Netherlands, the research institutes were abolished instead of being merged with universities[56], and there has not been an industry move to fund strategic research as in the case of Keygene.

As the report of the Agriculture and Environment Biotechnology Commission on Plant Breeding (AEBC 2005) states, plant breeding is near-market research (p.5). The withdrawal of government funding from near-market research can work in areas where there is a sufficiently large industry to fill this role. However, as explained in the previous chapter, the agricultural biotechnology sector is a low profit one and industry in the UK is not large enough anymore to fill this role. The 1993 White Paper acknowledge that there will be instances where some near-market work will be subject to market failure, such as in cases where the work is too generic, or the market is characterised by small firms, and it should be taken into account whether there are larger societal benefits (HMSO 1993: 16). In this sense, it can be claimed the government has not completely withdrawn from near-market research. Nevertheless, in the case of agriculture, where there are large benefits to society, the government's stance of withdrawal from such research has been very strong.

The recommendations of the 1993 White Paper resulted in a number of changes to the British innovation system. Firstly, the research councils were restructured. Together with the part of the Science and Engineering Council dealing with biology, the Agricultural and Food Research Council was transformed into the Biotechnology and Biological Sciences Research Councils (BBSRC)[57]. Secondly, new policy tools were created including the LINK programme, "a cross-government initiative which aims to bridge the gap between the science and engineering base and industry" (HMSO 1993: 35).

The Baker Report, "Creating Knowledge, Creating Wealth", which was published in 1999, called for "commercial exploitation to be given a much higher profile in the

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[56] There have been exceptions to this as in the case of Horticulture Research International, which until 2010 worked independently within Warwick University and is now a part of university's School of Life Sciences.

[57] According to two of the interviewees the change from AFRC to BBSRC is an example showing that the priority has shifted from agriculture to science (Company, UK).

Government's research establishments" (Boden et al.: 12). The report acknowledges that opportunities for knowledge exchange depend on the size and mission of the public-sector research establishment (PSRE), and the kind of science it conducts, as well as the nature of industry sectors to which their science is relevant (Baker 1999: 2). Baker argues that industries dominated by large companies, such as pharmaceuticals, have the resources to seek out and exploit public-sector research whereas in small, fragmented, or low-margin industries this will be less the case and ways of maximising 'industry-pull' should be sought (ibid.). This is precisely the case in the UK agricultural biotechnology and seed sectors, where the companies have lower profit margins. Nevertheless, the report does not present any concrete suggestions about how to overcome this problem. As mentioned in the previous chapters, programmes directed at increasing collaboration between university and industry can increase the use of public-sector research by industry, as opposed to policy tools aimed directly at commercialisation.

In 2000 the government published "Excellence and Opportunity: a Science and Innovation Policy for the 21st Century". This White Paper also concentrates on the role of excellent science and the importance of translating it into products and services (DTI 2000: 2). The paper places universities in a central role as the 1993 White Paper did previously: "The universities will be at the heart of this effort to build the knowledge economy. Universities can play a central role as dynamos of growth" (ibid: 27) .The language of the paper still resembles that of a linear model: "Innovation is the motor of the modern economy, turning ideas and knowledge into products and services", and "major innovations flow from breakthroughs made by curiosity-driven research" (ibid). This is almost like an extended technology-push model where universities are not only responsible for invention but also for innovation and diffusion of their own 'products', such as patents, licenses and spin-offs.

One of the important policy tools implemented following the publication of the 2000 White Paper is the Higher Education Innovation Fund (HEIF), which was "designed to support and develop a broad range of knowledge exchange activities which result in economic and social benefit to the UK" (HEFCE 2010). HEIF started in 2001 as a funding source where higher education institutions were invited to apply for grants. By 2005-06 it had become a permanent, formula-based third stream of funding for universities. Despite an increase in third-stream funding, the income from third-stream activities seems to be modest in comparison to total funding (Table 7.5), and also highly skewed in distribution, with a small number of universities earning the majority and around half of universities not making any money from IP income.

Table 7.5: Share of IP income over total income of UK universities

	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
Income from IP (£000s)	19874	23843	25640	28517	30815	33871	36908	43722
% of IP income over total income	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Funding council (£m)	5692	6055	6516	6967	7544	8031	8508	8819
% of funding council income over total income	39.3	38.9	38.6	38.7	38.7	37.8	36.4	34.9
Total Income (£m)	14491	15562	16867	17993	19487	21271	23376	25274

Source: Compiled by author from HESA data

In December 2003, DTI published "Competing in the global economy: the innovation challenge", reviewing the policies of the UK government that impact on innovation. Especially in reference to university-industry relations, the review argues that results are being observed based on the previous policies, showing the increasing number of spin-off companies, licenses and patents. As shown in table 7.5 above, an increase in numbers does not necessarily equate to 'progress'. More detailed information such as the percentage of companies that have survived, or the number of patents that have generated significant income should be taken into consideration to be able to make such claims. As in many other government documents on innovation, the review acknowledges the role of new knowledge with regard to innovation but does not include increased funding for the science base among the policy tools to create new knowledge. Instead, the focus is on strategic choices (through Technology Strategy Board), introducing measures and setting goals with Research Councils for increasing the rate of knowledge transfer (DTI 2003: 14).

The focus of government policies on universities and their role in contributing to economic wealth has continued, and in 2003 the "Lambert Review of Business-University Collaboration" was published. The report acknowledged a number of problems that were also raised in the interviews for this dissertation. One of these is the problem of universities setting too high a price for their IP; as the report notes, the main aim of technology transfer is "to benefit the economy as a whole rather than to create significant new sources of revenue for the universities" (HMSO 2003: 4). It was already mentioned in the previous chapter as well as in this one that agricultural biotechnology suffers from this particular problem.

The report also identified the demand side as the biggest challenge and argues that the main challenge is how to raise the overall demand by business rather than how to increase the supply of commercial ideas from universities (HMSO 2003: 3). The lack of demand from industry was also identified in the previous White Paper, which recommended the creation of an environment attractive for industry to innovate. Among the suggestions in the report on increasing demand from industry are building new networks and supporting existing schemes such as LINK and KTP, as well as directing government support for business R&D to SMEs. Although I agree with these suggestions, one should remember why industry collaborates with universities; for accessing fundamental and strategic research, which is too costly and risky for industry to conduct itself. Therefore, in the UK agricultural research system, increasing demand from industry may be stimulated by better crop science research, as will be explained in detail in the next section. While the focus is on weak demand from industry, the report also suggests expanding HEIF, which is more of a supply side tool rather than a demand-side one. Additionally, the discussion on supply-side vs. demand-side shows a continuing linear approach to innovation from the government. The problems in the demand side are explained by a decrease in defence expenditure, internationalisation and the disappearance of some large firms among other reasons. While the report makes a differentiation among mature and high-tech industries, in terms of their R&D expenditure, it does not really demonstrate an understanding about sectoral differences. Furthermore, while it suggests university-industry relations as the way forward, it does not acknowledge possible weaknesses in the current system in terms of the lack of certain organisations. For example, in the case of agricultural biotechnology, the lack or weak presence of applied research institutes is an important weakness in the system. This is taken up in the Royal Society response to the report as well, which states "…the situation differs widely across industry sectors, and it is important to understand the reasons why some sectors are less innovative than others" (2004: 2).

In 2007 the government published "The Race to the Top" - also known as the Sainsbury Review - looking again at the science and innovation policies of government with the aim of contributing to the competitiveness of the UK. Looking at the universities as well, the review makes a distinction between 'research universities' and 'business-facing universities'. The focus on universities' role of explicitly contributing to the economy continues in this review as well. Also suggested in this review are shifting the allocation of Higher Education Innovation Fund to a formula basis and setting 'firm knowledge transfer targets' for the research councils and their institutes and measuring them against these targets.

The idea of firm, measurable targets show that even if the terminology has changed to *knowledge* transfer, the underlying ideas are based on *technology* transfer. As widely discussed in this dissertation and the relevant academic literature, knowledge exchange is a much broader process than just the measurable activities such as patents, licenses, spin-offs and similar. A vision of targets seriously undermines the nature of this process.

While most of the government reports and policies regarding university-industry relations have focused on the supply side, some changes can be observed in the recent years. The 'Innovation Nation' report published by the Department of Innovation, Universities and Skills in 2008 suggests a shift from supply-side policies to demand-side policies. This report includes suggestions to increase demand for innovative products and services such as government procurement, the establishment of innovation platforms, and tools for small business stimulation.

7.5 The agricultural research system in the UK

The main actors of the agricultural research system in the UK post-World War II have been the Agricultural Research Council and its related institutes, the Ministry of Agriculture, Forestry and Fisheries and its institutes, universities and extension services. While the system reminds us somewhat of the triptych in the Netherlands, the governance of the different organisations is more complicated, especially in terms of funding.

The main restructuring of the public-sector agricultural research system started in the late 1980s with the privatisation of the Plant Breeding Institute (PBI). With its origins going back to 1912, PBI was one of the most important public sector actors in plant breeding research. The varieties developed by the institute were distributed to seed producers through the National Seed Development Organisation, and the commercialisation of technologies developed in PBI was carried out through the Agricultural Genetics Company. One of the strengths of the PBI was having basic and applied scientists under one organisation, somewhat similar to the current Plant Sciences Group in Wageningen UR.

One of the consequences of the privatisation of PBI, however, was the separation of basic and applied science. The 'basic scientists' in the Cambridge Laboratory were integrated into the Institute of Plant Science Research, which eventually became part of the John Innes Centre. The 'applied scientists', working on near-market areas as defined by government, formed Plant Breeding International within Unilever. As an academic from the John Innes Centre stated, the privatisation of PBI created a disconnection between fundamental research and its application, and they are still trying to rebuild this connection several years later.

A number of government institutes in agriculture in addition to PBI were either privatised or amalgamated, reducing the number of active institutes in agriculture drastically. In England there are now two main research institutes in agriculture that are of relevance to this dissertation: the John Innes Centre (JIC) and Rothamsted Research.

Several interviewees were asked whether there was a division of labour between universities and institutes in terms of conducting fundamental/ strategic/ applied science. A number of respondents indicated that the division of labour is less visible now compared to the past and that the main difference between universities and institutes lies in their ability to conduct long-term research. This was attributed mainly to the longer-term core funding that institutes receive from government.

While there are a number of universities in England with a plant sciences department, there is no equivalent of Wageningen University. As a number of interviewees from both countries mentioned, England is strong in plant science but weak in crop sciences for a number of reasons, which mainly revolve around the issue of funding. A review of BBSRC-funded research on crop science estimates that, although it is difficult to make a rigorous distinction between the two, the rate of increase around the 2000-2003 period is about 35% for plant sciences whereas it is only about 8% for crop sciences (BBSRC, 2004). However, the authors of the review acknowledge that making an objective and clear distinction between the two was difficult and indeed some of the crop science projects they accounted for may include "basic plant science undertaken on crop species" (ibid: 15).

The figures given by BBSRC regarding the relative share of plant and crop sciences is supported by a report of BioHybrids International and ADAS Consulting (2002), where it is stated that in 2001/02 the UK government spent £42.5M on plant genetic research of which £25.6M was for the model species such as Arabidopsis and £16M on UK crops. Of the total of £42.5M, only £4.8M was spent on applied research (p.9). These numbers support the argument that the balance may have shifted too much to excellence in basic science at the expense of applied research, as mentioned by interviewees and in other documents.

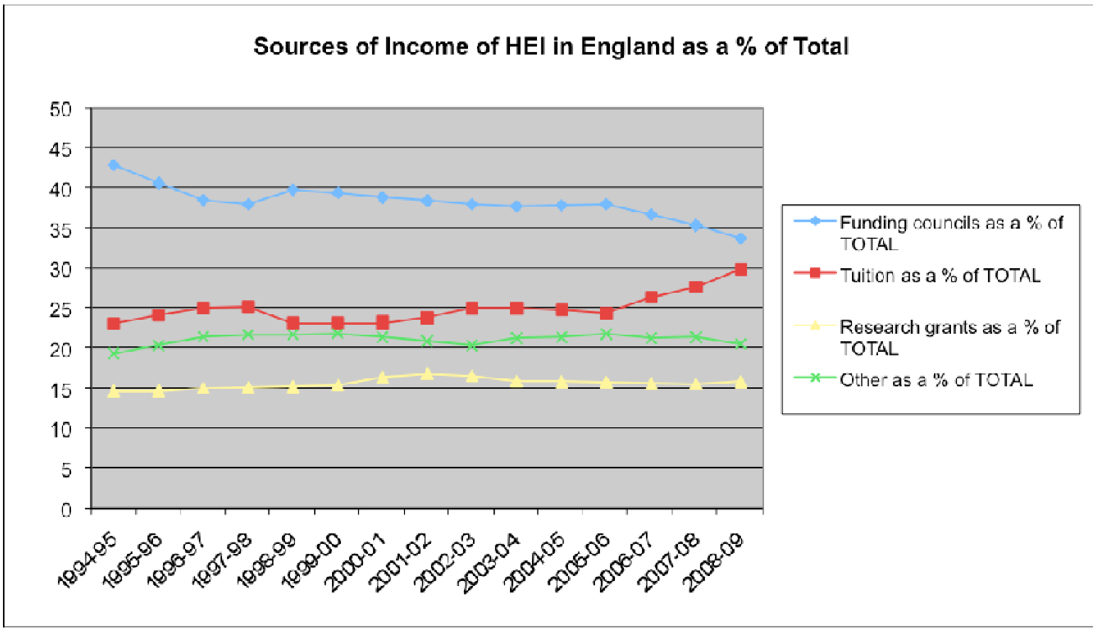
A comparison of the BioPolis project's national reports of the Netherlands (Enzing et al., 2007) and the UK (D'Este et al., 2007) shows that the share of plant biotechnology publications among the total biotechnology publications is roughly the same in both countries. On the other hand, while agro-food companies account for 24% of the biotech industry in the Netherlands, agricultural and marine biotechnology companies account for only 7% of the biotechnology industry in the UK. Although the drawbacks of these figures should be acknowledged[58], they still suggest that while the knowledge bases in the Netherlands and UK are comparable,

[58] While the company percentages give an idea about the relative size of the agricultural biotechnology sector in the two countries, there are important drawbacks in these figures; agro-food involves animal biotechnology and food related companies whereas agricultural and marine biotechnology involves marine and animal biotechnology companies, making it impossible to identify the actual percentage involved in crop-related biotechnology.

UK seems to be lagging behind in terms of translating the more basic knowledge in the agricultural biotechnology field into applications.

The first stream higher education funding through the funding councils in the UK (HEFCE) has decreased over the last decades while the share of second stream funding through research councils has increased (Figure 7.11). For 1994/95 the share of funding councils over the total income of universities was 44% but that had decreased to 35% by 2008/09, representing a 20% decrease. On the other hand, the share of research council funding over total income has increased by 9% from 2001/02 to 2008/09.

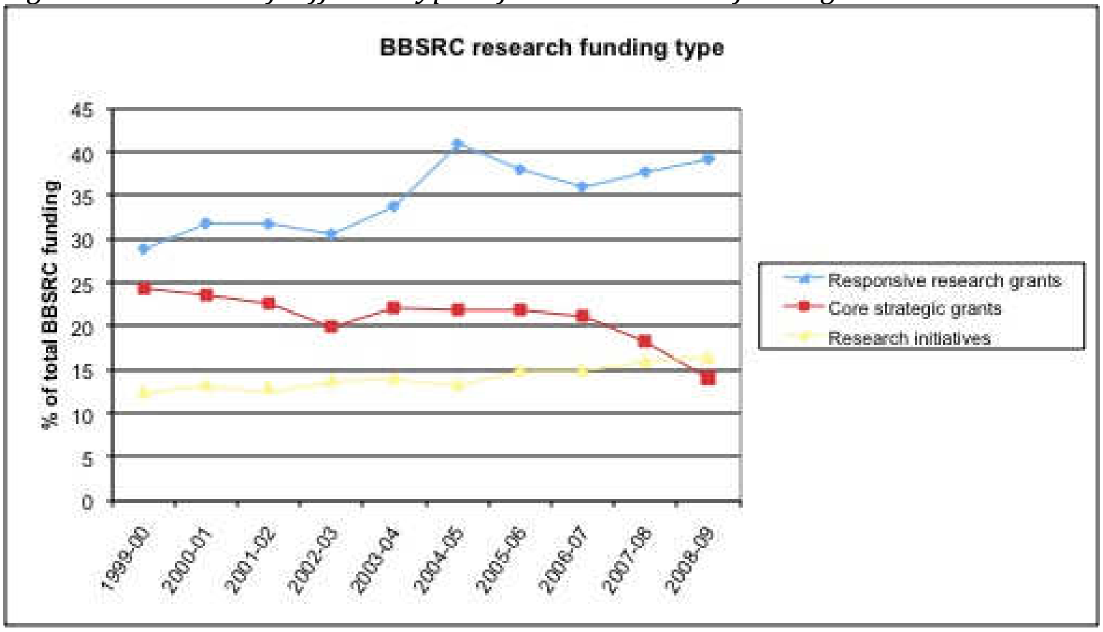
Figure 7.11: Share of first and second stream funding within total income of English universities



Source: Constructed by the author based on HESA data

The first stream funding for universities is allocated mainly based on certain indicators, whereas the second stream funding from research councils is allocated based on project applications. Research councils also provide a core funding for their research institutes, similar to the funding by HEFCE for universities. Similar to the decline in the share of HEFCE funding over all funding sources, the share of core funding within BBSRC has decreased in favour of responsive research grants (Figure 7.12).

Figure 7.12: Share of different types of BBSRC research funding

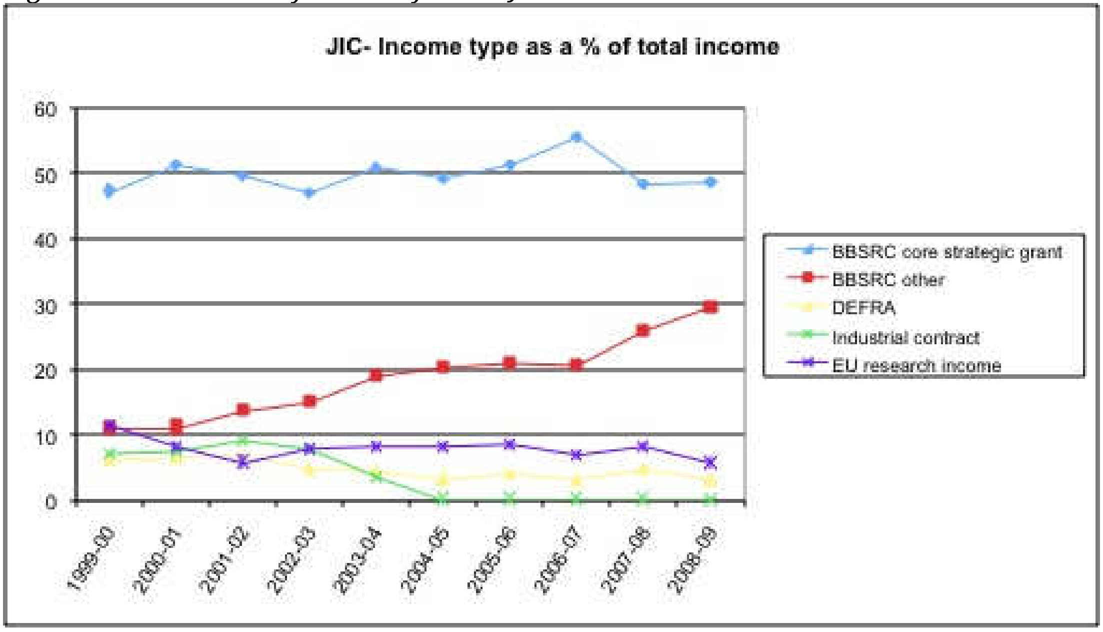


Source: Constructed by the author based on BBSRC annual reports

One of the academics mentioned that the main way of getting funded is through government agencies and the way they differentiate among projects is on the basis of the quality of science, and according to him "basic plant science projects will always serve better than the applied projects, because they are higher impact science" (university, UK). He believes that this creates a problem in getting funding for applied science, especially when there is not a strong industry to support it. He also added that universities are interested in scientists "who can bring in lots of money and publish very high impact papers", which is not generally the case with applied plant scientists (university, UK). He added that in order to transfer the information learned in basic science to crops, there is a need for people who understand crops (meaning applied crops scientists).

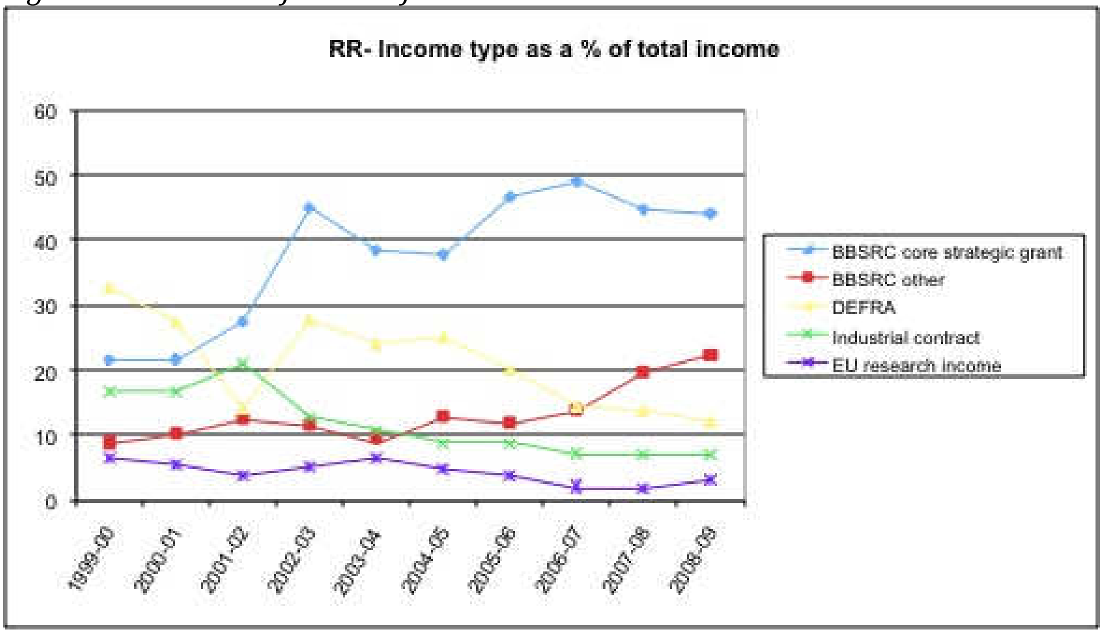
The funding sources for both the John Innes Centre and Rothamsted Research also indicate that the main source of funding for these institutes is their core strategic grant from BBSRC, and the industrial contract income has been declining in the last two decades (Figure 7.13 and 7.14).

Figure 7.13: Sources of income for the John Innes Centre



Source: Constructed by the author based on aannual reports of the JIC and BBSRC

Figure 7.14: Source of income for Rothamsted Research



Source: Constructed by the author based on aannual reports of the JIC and BBSRC

Another issue related to funding can affect the behaviour of academics towards commercialisation activities. Recurrent research funding for universities and core grants for research institutes, such as John Innes Centre and Rothamsted Research, are allocated based on the results of Research Assessment Exercise (RAE) and Institute Assessment Exercise (IAE) respectively. Both exercises evaluate scientists mainly on their academic outputs, i.e. publications. Given that funding council grants are still the largest single source of income for universities[59] and research institutes, it is not a large incentive for academics to work in commercialisation activities. It can be argued that in the case of agriculture, the low profit margins of the sector as well as the lack of a strong industry to absorb potential products tend to create further disincentives for academics.

The system of evaluation seems to create further conflicts in the case of research institutes. The institutes are expected to work within their remit or mission, which is serving the needs of their stakeholders, and especially in the case of Rothamsted Research they work more closely with farmers. So, overall, their mission is in more applied fields but at the same time they are expected to demonstrate academic excellence. As an interviewee from Rothamsted indicated", there is always a little bit of conflict between the Rothamsted mission and the pressures the scientists themselves are under as individuals" (PRO, UK), and they risk compromising their "ability to answer real nitty-gritty agricultural questions" because of the evaluation pressure.

In the cases where knowledge exchange is recognised in the IAE, it seems to be in the form of IP. In the reports of the visiting group for John Innes and Rothamsted, the section on 'knowledge transfer' evaluates issues around spin-outs, IP and licensing (BBSRC 2005). As an institute interviewee said, these may not be the most relevant indicators to measure knowledge exchange activities in agriculture: "…we had come to a realisation, and we are at the moment trying to persuade BBSRC that actually knowledge transfer for an organisation like ours is not predominantly through protected IP. BBSRC still struggle to accept this but I think we are making some small progress. They really struggle to accept it. Again in the Institute Assessment Exercise they want us to say how many patents and licenses." (PRO, UK).

7.6 Current system solutions in the UK

In Section 7.3 it was mentioned that one of the key features of successful institutions in agricultural biotechnology in the Netherlands was the broad participation of industry in programmes such as the Centre for Biosystems

[59] Funding council grants accounted for 35% of total university income in 2008/09.

Genomics and Technological Top Institute - Green Genomics as well organisations like Keygene. In the UK it is only more recently that similar institutions have been formed, which will be discussed in this Section.

The first kind of these institutions are the Genetic Improvement Networks funded by the Department for Environment, Food and Rural Affairs (DEFRA). These networks have been designed to address the "market failure in R&D supporting crop breeding", which is considered to be due to the "bottlenecks in the pipeline leading from basic research to applied breeding and cultivar production" which limits the ability of the breeding industry to introduce new cultivars (DEFRA 2010). It is debatable whether this is actually a 'market rationale' as the traditional market rationale for government investment in research is more related to assumptions about the non-excludability and non-rivalry characteristics of science, as discussed in Chapter 2, than bottlenecks. The presence of these bottlenecks suggests that there is a problem in the system in terms of the links between different actors and therefore it should be considered more as a system failure. The programme is mainly limited to funding of research, along with the underlying rationale, but nevertheless it takes a step further towards a systems solution by bringing in industry participation.

Another recent programme related to agricultural biotechnology is the Crop Science Initiative (CSI). The review of BBSRC-funded crop science in 2004 identified four major weakness related in UK crop science research: "no coherent strategy for crop research"; "investment in plant science is not yet impacting on strategic and applied crop science"; "fragmentation of funding within and between major funders is weakening the scientific strategy"; and "there is a shortage of suitably trained personnel" (BBSRC 2004: 5)[60]. All of these weaknesses have also been addressed by different interviewees for this dissertation.

Based on a review of crop science in the UK, BBSRC announced the establishment of CSI in 2005 to fund £11.6M[61] of research projects "to turn ideas from excellent plant science into practical applications" (JIC 2010). The initiative is open to

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[60] It is interesting that this review does not refer to the demand-side characteristics at all and focuses only on supply-side strength and weaknesses.
[61] The 2007 figures projected for CSI was £13M.

universities and research institutes and, although collaboration is encouraged, industry is not specifically mentioned among possible collaborators.

The final organisation that is of relevance to the UK agricultural biotechnology sector is the British Wheat Breeders consortium formed by three UK-based wheat breeding companies accounting for 92% of wheat acreage: Groupe Limagrain, RAGT and CPB Twyford (BCPC 2006). While the organisation reminds one of Keygene in terms being an industry consortium, it also seems to be less 'formal' as its existence is present in the meeting notes of some organisations and through the interviewees, but not much more than that. The few existing references to this group suggest that they act as a coordinating body in the (wheat) industry for defining priorities and strategies for the field and communicating with government. According to an interviewee from this group, what they have done is to get together and prepare a list of traits that are of importance to them (the breeders). The academic researchers perceived this positively as well, seeing that there is a common research goal among the research and industry members.

7.7 Country comparisons and chapter results

In this section I will compare the developments in policy rationales of the two countries and how these are interrelated with the agricultural biotechnology sector.

Looking at the changes in policy tools since the 1970s, one can say that the Dutch science, technology and innovation (STI) policies have moved towards a systems rationale for government intervention rather than a market failure one. This can be seen in several programmes that have been supported by government over the years, such as the Innovation-oriented Research Program (IOP) and the Technological Top Institutes where government funds strategic research with industry needs in mind. TTI-Green Genomics (TTI-GG) and the Centre for Biosystems Genomics (CBSG) are systemic in nature because they bring together a variety of actors together, such as university and industry, and fund not only research but also other aspects surrounding university-industry relations such as valorisation and training. These institutions are what can be termed 'intermediary institutions', in which the co-creation of knowledge takes place.

UK STI policies also now have a systems approach embodied in them but the tools used to reach this aim seem to be instead underlined with a market failure rationale. DEFRA Genetic Improvement Networks and the Crop Science Initiative remind us of the two programmes in the Netherlands with the aim of improving crop science. Nevertheless, their structure is considerably different in that the government primarily focuses on providing funding with the aim of improving weak areas of knowledge. Although industry is involved in collaborative projects under these programmes, their role in terms of strategy making is limited.

UK STI policies also address commercialisation and training activities but these are rather disconnected from each other. Initiatives for commercialisation, such as the Higher Education Innovation Fund, and for training, such as the LINK and KTP programmes, are national-level policy tools rather than being sectorally organised.

The participation of industry in agriculture in the Netherlands is on a different number of levels including funding, active participation in research and governance. In the UK this seems to be limited to participation and some funding, with very little role in governance.

As mentioned previously, one of the problems that is faced in plant breeding is that the number of trained people is falling, an issue raised in both countries (other institution, NL). In the Netherlands, this has been taken into consideration through involving PhD studentships within CBSG and TTI-GG projects as well as through the Graduate School of Experimental Sciences. In the UK, on the other hand, the training of people is still fragmented, as mentioned in previous paragraphs.

In Section 3.3 a number of different types of intermediaries were formulated; namely, transporters, hosts, transformers and translators. Transporters are organisations that are involved with the transaction and transfer of information. I could not find any generic national policies directed towards this type of intermediaries, and one possible interpretation of this finding might be that the transporters might have evolved in a more decentralised, bottom-up manner. On the other hand, commercialisation has been on the government agenda in the UK for much longer, and there are national level funds, such as HEIF, for the establishment of these types of intermediaries.

Translators are intermediaries that can translate basic knowledge from universities into more strategic and applied knowledge for industry. In the case of Netherlands, DLO institutes play this role in agriculture, even though they have been merged with Wageningen University under the same umbrella organisation. In the UK, the Plant Breeding Institute originally served such a role together with several other research organisations before they were privatised. It is possible to argue that the withdrawal of government funding from near-market research created a gap in the knowledge spectrum between basic and applied agricultural research – between plant science and crop science. Although there are still large and successful agricultural research organisations in plant breeding such as the John Innes Centre and Rothamsted Research, they lie towards the fundamental side of the knowledge spectrum, close to universities.

To conclude this chapter, one can state that both countries have developed policy tools addressing relevant actors related to the innovation system in agricultural biotechnology. I argue that the breadth of the policies in the Netherlands is larger and more systemic in nature considering they pay attention not only to the transfer of research results but also to a wider number of issues associated with knowledge exchange. Furthermore, policies seem to pay specific attention to the sectors, and organise around them. On the other hand, the UK has a more centralised system where policy tools are coordinated at the national level but fragmented at the sector level.

CHAPTER 8: SYNTHESIS

The aim of this chapter is to synthesise the findings presented in Chapters 5, 6 and 7, and to link these findings with the relevant academic literature discussed in Chapters 2 and 3. To remind the reader once more, Chapter 5 presented the general results of the interviews based on the five functions described within the conceptual framework. The five functions derived from the literature on university-industry interaction mechanisms and presented in Chapter 3 are: access to knowledge, human resources, access to networks, access to facilities and other infrastructure and increased opportunities for commercialisation. In Chapter 6, the characteristics of the agricultural biotechnology sector were discussed on the basis of concepts borrowed from the field of technological regimes, using a combination of primary data from the interviews and secondary data. Finally, Chapter 7 used the concepts from the national systems of innovation framework and showed how the institutional history and the specific configurations in the Netherlands and the UK affect the role of intermediaries in these two countries in relation to the agricultural biotechnology sector.

In this chapter a synthesis of the three previous chapters is provided by going through each function and then discussing whether there is an advantage or disadvantage offered by the different intermediary types. Each function will be briefly described again at the beginning of the relevant section. For each intermediary type, the effect of sectoral characteristics are discussed through the use of technological regimes as well as the effect of country-level differences.

Before going through the functions, it is useful to briefly remind the reader what were the different intermediary types discussed in Chapter 3 and the additional one suggested in Section 5.6. The first type is the 'transporter', an organisational type that does not make a contribution to the knowledge production process itself but merely transports a certain piece of knowledge or technology between the university and industry – usually in the direction from university to industry. University technology transfer offices (UTTOs) are the main example of this category. 'Hosts' are those organisations such as science parks where the organisation provides a particular context with the aim of facilitating the interaction between university and industry by bringing the two geographically closer. 'Transformers' are organisations that are able to ferret out knowledge or technology from the university and translate it to meet the needs of industry, without necessarily producing new knowledge. 'Translators' are those organisations that are not only able to ferret out knowledge or identify relevant technology but also add to the process of knowledge production due to their internal capabilities. Public-sector research organisations that lie between universities and industry are the main examples of this category. Finally, 'generators' are organisations or institutions formed jointly by university and industry – and sometimes other actors - for the purpose of knowledge production. Some large programmes mentioned in earlier chapters such as the Centre for BioSystems Genomics and the Crop Science Initiative are examples to this type of intermediary organisation.

It is also helpful to very briefly remind ourselves of the concepts that have been borrowed from the field of technological regimes, concepts that have been explained in more depth in Chapter 6. Technological opportunities "reflect the easiness of innovating for any given amount of resources invested in research"; technological appropriability refers to "the possibility of protecting innovations from imitation and of extracting profits from innovative activities"; and technological cumulativeness is related to learning processes, organisational sources and previous successes (Malerba and Orsenigo 1997: 94-95).

Sections 8.1 to 8.5 will discuss whether each intermediary organisation serves a role or not with respect to the function in question as well the reasons behind the presence or absence of that role. We will also discuss whether this is specific to the sector concerned or whether it can be extended more generally to the university-industry relations arena. Furthermore, in the case that a certain intermediary organisation type serves a role in one country and not the other, the institutional characteristics of the country leading to this difference will be discussed as well. Finally, Section 8.6 will make an attempt to schematise these findings and discuss the results of the synthesis in relation to existing academic literature on university-industry relations and intermediaries.

8.1 Access to knowledge

Section 3.4 described that access to knowledge function is a difficult one to draw the boundaries of and that it in this study it refers to knowledge activities there are not covered under other functions. These include activities such as contracts and collaborative research between university and industry. Activities that allow for knowledge exchange in a less direct way, such as networking or commercialisation, will be covered under subsequent sections relating to their respective functions.

As has been demonstrated in Section 2.2.1, companies like to collaborate with universities mainly in order to access knowledge lying at the more fundamental or strategic end of the spectrum. Fundamental knowledge is costly, risky and long-term in nature, and often lies in an area where companies do not have many skills. One would therefore expect that for any intermediary to have a role within this function, they should be able to increase access to more fundamental or strategic knowledge, or in other words to catalyse knowledge-based interactions.

Based on the interviews conducted in this study, it can be argued that the **transporter**-type organisations do not offer a direct advantage for either industry or university in terms of catalysing the relations between university and industry around knowledge-based activities. It has been repeatedly stated by both academic and industry interviewees that they are able to build and conduct such interactions directly without the need for an intermediary.

On the other hand, transporter-type organisations may give rise to certain indirect advantages and disadvantages in such interactions, mainly through either easing or further complicating bureaucracy. They can ease bureaucracy through managing the contracts between university and industry, giving academics more time to engage in research than in paperwork. However, as has been stressed by the interviewees, they can also disrupt the process of accessing knowledge. For example, as has been mentioned in Section 5.5, the interviewees in this study have mentioned a number of instances where the collaborations came to a halt because of the formalities presented by university technology transfer offices (UTTOs). We also discussed how UTTOs without certain competencies or experience in the agricultural biotechnology sector may create more problems than benefits. These disadvantages may not exist or may be less obvious in other sectors such as pharmaceuticals or IT, where UTTOs are more experienced in the field and cause less disturbance to the communication between university and industry. While it is not possible to say for all sectors that 'transporters' do not present any advantages, it can nevertheless be argued that they can create certain disadvantages depending on the sector.

In terms of country differences for transporter organisations, one can argue that the disadvantages they present in the UK are more pronounced than those in the Netherlands. In the UK there were more interviewees from both industry and academia expressing their discontent about the UTTOs as well as the disruptions they create through intervening in university-industry relations. One explanation of this could be that UTTOs in the UK are less competent than the ones in the Netherlands. Another explanation may be that UK UTTOs intervene more in university-industry relations than their Dutch equivalents. It can be argued that the explicit policies in the UK concerning the accountability of universities and the expectation that universities should contribute to the economy may increase the pressure on UTTOs to intervene.

Host-type organisations do not seem to offer any particular advantages for the agricultural biotechnology sector in terms of easier access to knowledge either. As mentioned in section 3.2.3, one of the justifications behind the establishment of organisations like science parks is increasing the interactions between university and industry by bringing them geographically closer. There may be both sectoral and country-level characteristics explaining the lack of any apparent advantages based on geographical proximity. As has been mentioned in Section 5.3, the agricultural biotechnology sector is small enough in both the Netherlands and the UK that geographical proximity seems not to matter so much and there is not an abundance of firms or research organisations. Another reason why such organisations may not be as important in the agricultural biotechnology sector may be related to the size of the firms in the sector. It was already mentioned in Section 6.2 that there are less dedicated biotechnology firms in agriculture – at least in Europe - and the sector is mainly dominated by medium-size and large firms. These firms may have less dependence on what host organisations have to offer compared to smaller firms. In sectors such as pharmaceuticals and IT, there is a larger population of small firms – for example, start-ups and spin-offs - which may make more use of host organisations. However, while hosts do not possess a particular advantage for the agricultural biotechnology sector, they do not create significant disadvantages either, which sometimes may be the case for transporters, as noted in previous paragraphs.

In addition to the above mentioned sectoral characteristics, which may be part of the reason behind the fact that there is less need for host-type organisations, there may be some country-level effects as well. While it is not possible to make a definitive statement, it can be assumed that geographical proximity would be less of a problem in the Netherlands compared to the UK due to its smaller size, and therefore companies there may not need to be located in a host organisation in particular.

Transformer-type organisations have no particular advantages or disadvantages for accessing knowledge. The consultancies that have been interviewed were usually quite small (1-2 people) and the people working in these consultancies often held an academic post at the same time. The consultants have talked about the services they provide such as technology assessment. However, none of the other firms have remarked upon using services from such consultancies, except getting help in writing funding proposals. As mentioned by one of the consultants, larger firms have in-house capabilities for conducting and managing research whereas smaller firms are more focused towards marketing and manufacturing, and it is those companies they have served. Considering also that large firms dominate research in agricultural biotechnology, it may explain why a role for consultants did not emerge during this study. It has to be noted, however, that although consultancy companies may not have a visible role, there may be more consultancy-activity taking place through individuals – i.e. academics working as consultants for companies.

Translators are the second type of intermediary organisations that were considered to generate advantages for accessing knowledge. As has been discussed in Chapter 7, public-sector research organisations (PROs) have been disappearing in both countries and there are a few new private sector alternatives emerging in response to this growing gap. While these organisations do not necessarily facilitate direct access of industry to university knowledge, they do offer knowledge themselves that is more directly relevant to industry's problems. As has been argued in Section 7.2, while industry is still able to gain knowledge that was previously provided by PROs, it has only been possible through an expansion of their research facilities or by pushing the borders of the remits of universities. While larger firms have more resources for such an expansion, the same cannot be said for small firms.

Furthermore, if this expansion is seen as an increase in the costs involved for industry to obtain the knowledge from university and to translate it to meet their needs, it can be argued that it also represents a decrease in the technological opportunities for industry. In other words, the existence of public-sector research organisations offers a less costly and more direct means of problem-solving for industry.

As was mentioned in Chapter 7, PROs in the agriculture field have been disappearing in both countries and there are examples of organisations emerging through the market as alternatives to PROs, such as Keygene in the Netherlands, conducting similar functions to those carried out by PROs. An organisation like Keygene is similar to the PROs in the way that it is situated between university and industry in terms of the kind of research it does. Nevertheless, the technology areas of Keygene are more limited than a PRO and the customers are mainly, but not solely, its stakeholder companies. There is also a difference between Keygene and PROs in terms of their funding structure; while PROs receive core funding from the government in addition to contract work, Keygene is funded through its stakeholder companies and the services it provides. Like the case of generators, through such a funding structure the costs of research and the risk are distributed among the stakeholders, possibly allowing them to conduct more research than they would do were they the sole funder. Furthermore, the strong involvement of industry likewise increases the chances of even the upstream work being more applicable. Considering that the research results would be proprietary rather than a public good, as in the case of PROs, there are increased appropriability chances for the industry and therefore a stronger incentive to conduct research on the more fundamental and strategic side. The sustained funding from the stakeholder companies also ensures the continuity of the research, something that matters to the companies and therefore increases the technological cumulativeness.

As has been demonstrated in section 7.3 in the absence of public-sector research organisations for conducting more applied research, the market can provide alternative solutions as in the case of Keygene, although the presence of a strong industry seems to be a condition for such an alternative solution to emerge. This may explain the reason why such an organisation emerged in the Netherlands and not in the UK, as the industry in the UK is smaller compared to the Netherlands in certain aspects. The estimated size of internal commercial market for seed and other planting material is larger in the UK, although a large part of this is farm-saved seed. When the exports are compared, the difference is more obvious, in that the Netherlands makes up for 47% of total EU export of seeds and planting material, whereas the UK accounts for only 3% (Kamphuis 2005)[62].

It was also apparent from the interviews conducted for this study and from relevant academic literature that the privatisation of the PROs in the UK working in the field of agriculture meant a reduction in the specialised knowledge and essential agricultural material, possibly hampering the cumulative development of the sector in general.

Generator-type institutions were considered to offer a number of pronounced advantages for both universities and industry in both countries, as was discussed more extensively in previous chapters. To remind us again, large programmes such as CBSG and TTI-GG in the Netherlands, and Genetic Improvement Networks and the Crop Science Initiative in England are current examples of such institutions within the agricultural biotechnology sector. Such programmes present increased technological opportunities for a number of reasons. Firstly, due to joint funding by the parties involved and/or government funding, they present the chance to benefit from a large-scale research programmes for a much lower cost compared to what the participants would need to pay should they do it alone – if they can, that is. Secondly, it allows industry to participate in more fundamental or strategic

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[62] On the other hand, it should be remembered that the ornamentals category makes up a third of Dutch exports and the exclusion of this sector would decrease the share of Netherlands.

research programmes, which are inherently more risky compared to applied research or development. Again, due to multiple funding sources and the relatively lower cost per participant, the risks for a given amount of investment per participating organisations are substantially lower as they are distributed among the participants rather than being focused on just one. For universities, the technological opportunities are increased as well by having extra funding, but they also benefit from such programmes by getting industry feedback on the research they conduct in terms of its applicability to the market. To open this up, it was mentioned by interviewees that one of the problems in the transfer of academic knowledge into real world application was the premature stage or an unrealistic understanding of the commercially-aimed output from universities. The early participation of industry in the research process provides a 'reality check' about the potential applications of the project outcomes.

In terms of technological cumulativeness, the relatively long-term funding provided by these institutions[63], compared to the shorter-term contract research type of work, allows a continuum of research. As has been mentioned in section 6.1.3, agriculture and plant breeding in particular need a long-term perspective due to their nature, and a longer-term project matches the needs of this nature.

While such programmes have created a number of benefits such as strategic knowledge for industry that can be used in problem solving, one needs to recognise that the interviewees who mentioned these advantages were mainly in middle and large-sized companies. Smaller firm participation may be a problem due to the lack of financial means to contribute to the project or because they have less capacity to follow and be informed of such projects or to deal with the bureaucracy that inevitably comes with them.

There were country-level differences observed among the generator institutions. Strategic focus and industry leadership as opposed to industry participation only are two important characteristics observed in the Netherlands. Within the CBSG programme, a limited number of crops have been chosen for research that are of

[63] The initial phase of CBSG was between 2003-2008 with a budget of €53m and it has since been extended for a second phase between 2008-2012 with an equivalent budget. In the case of TTI-GG, the budget is €40m until May 1st 2011.

importance to the Dutch industry. This is in line with the ‘critical mass’ idea expressed in Dutch policy documents, as mentioned in section 7.1. Industry leadership as opposed to academic leadership is a characteristic of the TTI-GG programme, which does not have an equivalent in the UK in terms of giving direct control to industry. One question that may arise here is why there is a programme in the Netherlands with direct control of industry as opposed to the UK. Firstly, it can be argued that TTI-GG is complemented by CBSG, where the control lies with universities and the industry presence is more limited to participation, Therefore an industry-initiated and controlled programme does not represent a competition of funds but rather an additional source of income for universities. Secondly, the industry in the Netherlands showed not only an initiation but also contributed significantly to funding of such a programme[64]. In the UK, a similar example would be the British Wheat Breeders, which proactively tries to affect the research agenda by identifying fields of research that are of relevance to industry. Nevertheless, in contrast to their Dutch counterparts, they are limited in their financial ability to contribute, or they are not willing to do so. Finally, in the Netherlands the government was willing to provide funding for research that is of strategic nature, whereas the UK government policies since the mid-80s has been to withdraw funding from near-market research[65].

8.2 Human resources

Transporter-type organisations were not seen as offering any particular advantages or disadvantages, according to the interview results. This is in accordance with the literature reviewed in Chapter 2; there is no evidence of a role for transporters in this area and in general it is not within their remit anyway.

As in the case of transporters, **hosts** have not apparently provided any significant advantages or disadvantages in terms of easier or increased access to human resources, regardless of whether it was the Netherlands or the UK. However, the results may be limited to the particular field studied in this dissertation, since previous studies have indicated certain advantages provided by host-type

[64] TTI-GG’s budget is €40m of which €20m comes from the government, €5m from participating research organisations and €15m from companies.

[65] There have been some changes within the agriculture sector in the last few years with the Crop Science Initiative, as has been discussed in section 7.6.

organisations.

In Chapter 3, **transformers** were described as those organisations that are able to explore knowledge from universities and other relevant sources and to transform it to meet the needs of industry. If we restrict things to this definition, there was not a clear role or advantage presented by brokers in terms of easier or increased access to knowledge. However, there was a role for specialised human resource agencies in the recruitment of more senior managers, as mentioned in chapter 5. These agencies can be classified as a type of broker organisation as well, since they explore a larger domain of opportunities - people in this case - and filter these down to those that specifically address the needs of the industry. Such organisations were considered by the interviewees to be useful in both countries.

Translators have an indirect but nevertheless important role in accessing human resources. As described in chapter 5, the old public-sector research organisations had employees who were specialised in certain areas. Through their person-embodied skills and capabilities, they provided an important advantage for industry. Scaling down of these organisations has resulted in a decrease in the number of these people as well, at least in the public sector.

In addition to offering advantages in terms of knowledge access, **generator**-type organisations – or institutions - such as the large programmes were considered by the interviewees to be advantageous for the human resources function as well. Large programmes like CBSG provide a means for educating people in plant sciences for both university and industry - an area considered to be weakening by interviewees in terms of the supply of suitably trained human resources. Through joint funding of students, the cost is divided between the various parties, and it can therefore be argued that the technological opportunities are increased. Furthermore, the training of students also contributes to technological cumulativeness through the dissemination of knowledge from older to younger researchers.

It was mentioned in section 5.7 that in addition to the five intermediary organisations, intermediary institutions such as regulations and government schemes should be taken into account as well. In the same section it was also discussed how the two countries have different programme and regulations, which are favoured by both industry and university. In the UK, programmes such as LINK and CASE, which are jointly funded by government and industry, are examples of such institutions. Such programmes are considered to be beneficial by industry because they offer the chance to conduct risky research in a cheaper way and thus increase the range of technological opportunities by decreasing the cost. It can also be argued that they increase technological cumulativeness by training students and also by contributing to the supply of skilled graduates for future employment. Furthermore, by providing the students with an understanding of the industrial world and its needs, this tends to reduce the problems of overvaluation mentioned in section 5.5, helping in the appropriability processes. To recall, it was mentioned in section 5.5 that sectoral technology transfer companies such as PBL were considered by interviewees to be successful, as they are often run by people who have both academic and industrial experience.

Based on my interviews, one of the most prominent policy tools regarding human resources function within the agricultural biotechnology sector in the Netherlands, one that creates advantages for both university and industry, consists of the regulations allowing mobility between the two sectors. Although no government funds were mentioned for supporting mobility activities, it can be argued that the flexibility of the regulations facilitates dialogue between university and industry personnel. Through increased communication and involvement in the each other's worlds, the range of technological opportunities is increased for both parties. Earlier literature looking at university-industry relations confirms the importance of labour mobility not only because it increases the accessibility of firms to knowledge but also because it increases the awareness of commercial markets among academics (Bartholomew 1997). Furthermore, it is argued that the mobility between university and industry is affected by the "norms and practices of nation's research institutions" (ibid: 248). It has been noted in different articles that the UK scientists may have a negative attitude towards collaboration with industry stemming from a belief that "pure" research is superior to "applied" research (Scott-Ram 1993: 668). Such a historical negative attitude towards collaborating with industry can help in explaining why two-directional mobility[66] between universities and industry have not been observed in the case of UK.

8.3 Networks

Almost all of the academic interviewees in both countries mentioned that they do not use any third party organisations or institutions for accessing people, something that was confirmed by intermediary organisations such as UTTOs. Academics use events such as conferences, seminars or projects to extend their networks, and when they need to contact people with the right knowledge, they either conduct a search or use their existing networks to make direct contact.

One of the areas where the **transporter** type of intermediary organisations offered an advantage was in the networking function. As has been explained in section 5.3, transporters such as university technology transfer offices (UTTOs) can play a role in finding funds for academic work that is outside the core area of academics. In the case of opening up to non-traditional funders, it can be argued that they increase the technological opportunities for university and industry by making it easier to find funding or academic partners, which they may have not found otherwise.

We have mentioned several times that catalysing interactions between university and industry through geographical proximity is one of the building blocks of **host-**type intermediary organisations such as science parks. However, as was explained in section 5.6, this facilitation has not been remarked upon during the interviews and no country-level difference has been observed.

Transformer or **translator** type intermediary organisations were not mentioned as playing a role in providing increased access to networks by either university or industry interviewees in both countries.

Generator-type organisations catalyse the process of networking by providing a platform for the relevant actors from different sectors to come together. As such, they offer a chance of increasing the range of technological opportunities. It can be

[66] In this case, mobility refers to temporary mobility in terms of secondments and guest lectureships rather than changing jobs. The latter type of job mobility has indeed been studied by the likes of Zucker et al. 2002, Nauwelaers & Wintjes 2001, and Crespi et al. 2007 among others.

argued that networking, through strengthening the relations between university and industry, also provides a chance for increased technological appropriability as the applicability of a research outcomes into commercial products can be discussed beforehand in contrast to the passive transfer of a codified piece of knowledge, which may or may not have any applicability in industry.

8.4 Facilities and other infrastructure

It was mentioned in section 5.4 that firms do not consider universities as appropriate organisations for conducting more routine service work such as testing, registration and so on. The main reasons for this perception were the high costs of such services in universities, the lack of appropriate skill sets and the unsuitability of such services given the remit of the university.

It can be argued that the above reasons tend to decrease the technological opportunities for companies. Therefore, any intermediary that can play a positive role here should increase these opportunities.

The **transporter**-type organisations have not revealed any particular advantage or disadvantages in terms of access to services or infrastructure. This is consistent with the TTO literature discussed in chapter 3, which did not attribute a role to TTOs in providing technical services[67].

The **host**-type organisations do not necessarily facilitate an infrastructure-based relation between university and industry, but certain advantages were mentioned, even if they are not related to knowledge exchange directly. In the case of the Netherlands, one of the spin-off companies interviewed was located in an incubator because of the office space it provided. Similarly, as explained in Section 5.4, another small company in the UK was located in a research centre because they could make use of the services provided by that research centre. Although the services provided by the incubator or the research centre are not necessarily cheaper than those located elsewhere, several interviewees mentioned that being located there saved them time and thus increased their efficiency.

While **transformer**-type organisations such as consultancies were not mentioned

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[67] The term ‘technical services’ is used here to differentiate them from more managerial, commercial or bureaucratic services that TTOs carry out.

as offering clear advantages or disadvantages, there was seen to be a role for private contract research organisations. During the period of structural change in the sector with mergers and acquisitions, there were some private contract research organisations formed by former employees of larger agrochemical companies, which now provide services for the sector. However, it is debatable whether these organisations can be truly called intermediaries within the boundaries of the definition given in this dissertation, as these organisations are ultimately private companies and do not aim to be specifically located between universities and industry.

Translators in the traditional sense, such as the PROs in the Netherlands and the UK, have played an important role in the services and infrastructure, as mentioned clearly by interviewees in both the public and private sectors. While the scale and scope of these organisations have been diminishing, particularly in the UK, they provide services to firms such as field-testing for plant sciences or chemical analysis in the agrochemical sector. This also fits within the remit of these organisations, which is to help industry in the first place.

It can be argued that, with the decline of these institutes through privatisation, closure and so on, a gap has emerged in the system, which was then filled by private companies. Keygene, for example, provides services in the field of marker-assisted selection, while contract research organisations that were spun off from multinational chemical companies carry out chemical services for these large companies.

Generator-type organisations offer several indirect advantages related to infrastructure. Firstly, they can provide funding for purchasing equipment for the public-sector research organisations involved. Secondly, by bringing together PROs and private companies, they provide the opportunity to use each other's facilities within the programme. Several industry interviewees mentioned that they participate in collaborative projects through providing services such as field-testing, greenhouses and the like. Considering that university researchers in both countries complain about diminishing resources for such facilities, facilitators can provide increased technological opportunities for all parties involved.

8.5 Commercialisation

As has been noted in Chapters 2 and 3, technology transfer is often reduced to commercialisation activities by scholars and policymakers, and a lot of attention has been paid to this area in the form of funding programmes, new organisations and so on. Therefore, one might expect the intermediary organisations to play an important role with regard to this particular function.

Transporter-type organisations play the most direct role in regard to this function. As explained in section 5.5, whether the role they play creates advantages or disadvantages depends on the organisation and its characteristics, which in turn is also affected by the sectoral and institutional configuration of the country.

A well functioning transporter organisation arguably increases, first and foremost, the level of technological appropriability for both university and industry. For a university, a well functioning transporter provides skills and capabilities that academics lack or only possess in a less developed form, such as legal and bureaucratic procedures or the assessment of the market value of their products. As discussed in section 5.5, it was mentioned by several interviewees, from both university and industry, that academics without industrial experience can often overvalue their inventions. However, the same problem also exists for university technology transfer offices (UTTOs) that are inexperienced in a certain sector, namely agricultural biotechnology in this case. It was also shown that the problem of overvaluation can slow down or even halt the negotiations between university and industry. Therefore, a UTTO or a similar organisation should be able to facilitate the negotiation process and hence increase the technological appropriability. This was the case of the Plant Biotechnology Limited and Amaethon to a certain extent; as experienced technology transfer companies, they were considered by both university and industry to possess certain advantages in terms of sectoral knowledge, connections and experience. On the other hand, an inexperienced transporter organisation may not be able to judge the appropriability conditions properly and therefore present a disadvantage for the transactions between university and industry.

While the results indicate that experienced organisations can offer certain advantages, the differences between the Netherlands and the UK suggest that the institutional characteristics of a national innovation system can have an effect on the role of intermediary organisations too. This can be seen in the example of the Wageningen Business Generator, which was shut down a few years after it started to operate. Despite having experienced people working for it, and despite having a very specific focus in contrast to general UTTOs, the idea of a central technology transfer system has not been well regarded among researchers, who were used to more decentralised operations.

Host organisations were not mentioned as actors in the commercialisation process. As has been mentioned in previous chapters, the interviews indicate that these organisations mainly provide a locational and/or reputational advantage rather than being directly involved in the actual commercialisation process.

Transformers may or may not have a role in the commercialisation function, depending on how they are defined. For example, while a role for consultants has not been remarked upon in the interviews, there is certainly a role for specialist technology transfer companies like Plant Biotechnology Limited, if they can be classified as brokers. While these organisations do not add to the process of knowledge production or innovation, they do technology-scouting and also combine different technologies to make useful packages that can be presented to industry. Through this process, they increase the level of technological appropriability because they have an understanding of what industry wants from universities and which innovations from universities have potential value for industry. Furthermore, because of this knowledge, they are able to negotiate with industry with realistic demands, a skill that several transporter organisations seem to lack.

Such specialist technology transfer organisations have been observed in the UK context but not in the Netherlands. Wageningen Business Generator is a somewhat similar organisation in terms of being focused on agriculture, but this is mainly due to the fact that Wageningen University itself is focused on agriculture. Not having to build their experience on pharmaceuticals, they would not be expected to have unrealistic or overvalued demands in agriculture, which is positive, but in their case their activity was not welcomed by academics for other reasons.

Transfer-type organisations were not mentioned as having a particularly important role for the commercialisation function. However, this might also be due to the fact these organisations in the agriculture field have been mainly privatised or amalgamated. These organisations were established to help solve industry's problems in the first place and therefore their foundation is based on problem-solving rather than making profits through the application of intellectual property protection.

Generator-type organisations serve a useful role in the commercialisation function as well. It was mentioned that in the case of the CBSG there was a specific fund for valorisation purposes. As has been mentioned in previous sections, such organisations can contribute to the level of technological appropriability by ensuring that universities and industry work on a subject that is of interest to both parties, and therefore they not only facilitate innovative processes but also increase the chance of their application by industry

One of these aspects is the regulations involved. An important example of the effects of regulations has been observed for the human resource function. It was mentioned earlier that in the Netherlands academics were allowed and even encouraged to work in companies and vice versa. In the Netherlands a two-way flow was observed, and specific regulations in place for this were mentioned as well. In the UK it is possible for academics to work as consultants for industry but mobility in the other direction - i.e. industry people formally working in the university - has not been much observed.

8.6 Conclusions

In the previous sections of this chapter I have attempted to make a synthesis of the previous chapters by discussing the role of different intermediary organisation types for the five functions explained in the conceptual framework chapter, paying particular attention to the sectoral and national characteristics. In chapter 5 the results of the interviews were presented and compared with the existing academic literature. While some of the findings conformed to other works on university-industry relations, some did not, particularly due to the sectoral and national characteristics, which were then discussed in chapters 6 and 7. In this section, I will take a step further from discussing the specific findings and relate my results to certain broader concepts, some of which were alluded to in chapter 2. Before going further into these sections, I attempt to present the findings underlying these discussions in table 8.1; a matrix of intermediary types vs. the functions including country differences. This will not only help in presenting the overall picture in a simpler manner, but also reveal the country differences more visibly.

Where the findings suggest that a particular intermediary type provides certain advantages or disadvantages, it is marked by a (+) or (-) respectively, Finally, if there are both advantages and disadvantages presented by a certain intermediary type for a function, it is marked by both a (+) and a (-). Although these findings cannot be measured, it is still worth making an attempt to show the strength of the respective advantages and disadvantages based on the qualitative findings. Such a table should also help to form a base for further studies that may integrate more quantitative indicators. The table is followed by case illustrations where an advantage or disadvantage is observed for a certain function of different intermediaries to better demonstrate why these certain observations are reached.

Table 8.1: Intermediary types vs. functions

	Knowledge		*Human Resources*		*Networks*		*Services/ infrastructure*		*Commercialisation*	
	NL	UK	NL	UK	NL	UK	NL	UK	NL	UK
Transporter		(- -)				(+)			(++)	(++)
Host								(+)		
Transformer	(+)		(+)	(+)						
Translator	(++)	(++)					(+)	(+)		
Generator	(+)	(++)		(+)	(+)	(+)			(+)	

Based on the findings (+), weak positive role, (++) strong positive role, (-) weak negative effect, (- -) strong negative effect

Three broad themes of discussion emerge from the findings of this dissertation in relation to the academic debates discussed in chapter 2. The first of these is the importance of sectoral characteristics, particularly the variations within the general biotechnology 'umbrella'. A second theme is the importance of national institutions and how they can lead a particular sector down different paths. The final theme is the importance of a systems approach and the interdependency between the elements of a system. A discussion of these three themes will also pave the way to the policy implications, which will be discussed in the last chapter.

Biotechnology, but which biotechnology?

It was noted in section 2.2.2 that as well as the economical and political factors, the emergence of new fields such as biotechnology have contributed to the intensification of university-industry relations. The emergence of modern biotechnology has undoubtedly contributed to an increase in the level and variety of commercialisation activities undertaken by universities. Many academic researchers have looked at different aspects of university-industry relations within the biotechnology sector, trying to analyse the elements that lead to successful relations. Nevertheless, biotechnology is too large of a field or sector to derive a recipe from for successful university-industry relations. A large number of studies on biotechnology have focused on medical biotechnology, which is a more lucrative field with denser connections. While there have been studies that have drawn attention to the unique characteristics of medical biotechnology and to the limitations of this field as an exemplary one, studies on other sub-fields or sub-sectors of biotechnology have been much more limited.

The findings of this dissertation do not contradict a large part of the academic literature looking at university-industry relations in biotechnology. Similar to the outcomes of this dissertation, studies looking at biotechnology in general or medical biotechnology confirm the importance of skilled human resources, informal channels of knowledge exchange and the role of universities in conducting fundamental research. The point where this dissertation diverges from what can be labelled as 'mainstream' biotechnology, is regarding the appropriability conditions within the agricultural biotechnology sector.

For the pharmaceutical and the associated medical biotechnology sector, patents do play an important role and they can be very lucrative as well. The profitability of the sector makes it possible for companies in this sector to afford dense relations with the science base. In addition to the science base, pharmaceutical companies often benefit from the presence of dedicated biotechnology firms in this field, and it is common for such firms to be formed by academics as spin-offs. These and other characteristics of the sector have certain implications for the intermediary organisation types, particularly for transporters, which have been considered as the most problematic organisational type within the agricultural biotechnology sector. Transporters such as technology transfer offices in universities are more experienced in the pharmaceutical sector compared to the agricultural sector.

As mentioned in earlier paragraphs, while the results of this dissertation do not contradict the mainstream biotechnology literature, it does differ with regard to the policy tools, which might often be based on the particular characteristics of the medical biotechnology sector. Nightingale and Martin argue that “the idea of a biotech revolution has increased policy emphasis on closer networking between university researchers and industry” (Nightingale & Martin 2004: 564). Furthermore, relatively short times from invention to commercial application observed in the medical biotechnology sector seem to have set an example for policy documents as well: “The pace of development of health technologies is increasing, and the interval between scientific discovery and practical application is diminishing. This will lead to improved services and quality of life, with important consequences for the *wealth-creating* [emphasis added] capacity of the nation” (HMSO 1993: 1). Where this matters is when such underlying assumptions are translated into policies:

> “The successful translation of the fruits of academic research into a commercial ‘product’ is, in the first instance, dependent on successful technology transfer mechanisms…The realisation of this fact and a growing awareness of the commercial potential of much academic work has led to a spread of Technology Transfer Offices (TTOs) across UK universities...” (HC87 2003: 16).

The results of this dissertation show that different sectors function in quite different ways, and therefore policy mechanisms devised on the basis of particular assumptions may not be suitable for a sector that does not fit these assumptions. In the case of agriculture for example, the time between invention and commercial application is not short, and as discussed in the previous chapters, translation from basic research into commercial application is dependent on a number of factors that are more essential than technology transfer mechanisms. One of these is the nature of the technology and sector (as discussed in chapter 6) as well as the institutional context the sector is located in (as discussed in chapter 7). This brings us to the next theme - the role of national institutions.

The paths that a sector can take: the role of national institutions

One of the emerging themes in this dissertation is the role of national organisations and institutions with regard to innovation. While this study has compared the Netherlands and the UK agricultural biotechnology sectors, it has also benefited from contrasting these with the US. Contrasting Europe with the US draws our attention to two national institutions: the regulatory system and the intellectual property laws, While the regulatory system is another topic on its own, it has been evident that one of the reasons as to why there is a smaller agricultural biotechnology sector in the Netherlands and the UK compared to the US is the ban on genetically modified food in the former. However, even more relevant to this dissertation is the difference between the intellectual property regimes. As has been discussed in chapter 6, while the US grants utility patents for plants as well as plant variety protection, in Europe this is limited to the latter. This, in turn, limits the profitability of the sector.

However, a comparison of the Netherlands and the UK showed that there are further elements of national systems that can affect the way that a sector develops. One of the main differences between the two countries was the composition of the academic research system in agriculture. We have seen that the Netherlands has a dedicated university for agriculture as well as public sector research organisations working in this field, covering a spectrum ranging from basic science to more applied science. On the other hand, the findings indicate that while the UK institutions are strong in basic science, there is more of a gap on the applied side.

It was also shown that the differences mentioned in the above paragraph are a result of the different science, technology and innovation policy trajectories followed in the two countries. Universities in the Netherlands still enjoy larger proportions of funding support from the government as well as more autonomy. On the other hand, the share of government funding for universities in the UK has declined considerably and its composition has changed too. Along with the focus on 'wealth creation', UK universities' funding has shifted in favour of more directed funding. Furthermore, the research evaluation system has contributed to pushing universities, and research institutes in the case of agriculture, towards basic science.

In addition to the knowledge and skills, differences in the industry and supply side in the innovation systems have been observed. The Netherlands has a relatively stronger plant breeding sector compared to the UK, due to a number of factors. It can be argued that one reason for this is that the Dutch companies are willing to spend money on R&D, as observed in the case of Keygene and Technological Top Institute- Green Genetics. Nevertheless, it can also be argued that the willingness of the companies to invest in R&D is affected by the possible technological opportunities in the country. In the case of the Netherlands, government funds not only PROs (in this case DLO institutes) but also it funds large collaborative programmes like the TTI-GG. On the other hand, the UK government has largely withdrawn from near-market research, which has resulted in the contraction of the PRO sector and therefore of translational research.

The above paragraphs show that the functions of intermediaries depend on a number of factors, and it is not simply a matter of 'bridging the gap'. The next section will focus on the idea of interdependencies between the elements of a system and why it is necessary to have a 'systems failure' approach as opposed to the 'market failure' one.

A systemic approach

As discussed in section 2.1, and summarised by Edquist (2005), scholars working in the innovation systems field agree upon some essential assumptions underlying the field. Firstly, firms seldom innovate in isolation, interacting with other organisations in the system. Secondly, the institutions within a system affect the way that organisations behave. The findings of this dissertation confirm these assumptions.

Section 2.1 discussed how proponents of the innovation systems approach argued that the 'market failure' approach should be replaced by a 'systems failure' one. The main policy tools to overcome market failure are the government funding of basic research (or the direct production of knowledge by government) and mechanisms for strengthening intellectual property rights. The main policy tools associated with systems failure concern the establishment of appropriate institutions and the links between them.

The distinction between these two approaches can help to explain the advantages and disadvantages of different intermediary types as represented in table 8.1. Transporters, within this study, were considered mainly to present disadvantages. It can be argued that the main reason for this result is that they attempt to overcome a market failure, when there is not one. In addition to generating additional income for universities, it is argued that commercialisation activities such as patenting or licensing overcame the non-excludability and appropriability problems. Nevertheless, we have seen that within agricultural sector of Europe, these problems are overcame by other mechanisms such as plant variety protection rights. Therefore, by trying to apply IP protection mechanisms from different sectors conditions to agriculture, inexperienced transporter organisations do not help to increase the appropriability conditions but on the contrary tend to decrease them. Nevertheless, it should be noted that the positive perception of sector-specific transporters suggests that this is not necessarily a problem of 'transporter' types in general but of those that are not skilled enough for the sector. While there are examples of transporters being perceived positively, the interviews strongly suggested that these IPR mechanisms are not the most important factor in the translation of basic research into commercial products.

On the other hand, translator and generator type organisations were considered to present mainly advantages. In the case of translators, the main examples were PROs and private organisations like Keygene, which are organisations that act as links between the other actors of the system, namely firms and universities, Again, in the case of generators, large collaborative programmes like TTI-GG, CBSG, or Genetic Improvement Networks link together different actors and thus enhance learning.

The positive and negative perceptions of intermediaries also relate back to the discussion in section 2.3 about the need to shift from a 'technology transfer' view to a 'knowledge generation' one. Transporters are based on a technology transfer view, and suggest a linear, uni-directional move of technology from one domain to the other. While this is a subset of knowledge exchange, it has already been mentioned that it is not considered to be the most important or effective mechanism of getting knowledge from universities. On the other hand, one can argue that one of the reasons why translators may be considered positive is because they allow for a bi-directional flow of knowledge and create a context for learning. The generator-type intermediaries not only allow for a bi-directional flow of knowledge but also the co-generation of it. In this sense, it can act as the broader 'umbrella' above technology transfer and knowledge exchange.

While one might argue that co-generation is what the Triple Helix model suggests, there are important differences. The most important one is that both university and industry maintain their distinctive roles as opposed to taking on each other's roles. The co-generation is in the form of strong feedback loops, with industry contributing through techniques, material, funding and direction, and university conducting more fundamental and strategic research along these feedbacks. Universities are indeed specialised in conducting the latter kind of research, which is also what industry is often looking for.

CHAPTER 9: CONCLUSIONS

The last section of chapter 8 linked the findings of this study back to the literature. In this chapter, I will firstly present how these findings make a contribution to knowledge followed by a discussion of the policy implications emerging from this study, which is particularly important considering that the research problem of this study was motivated by a policy problem. In the last two sections, I will discuss the limitations faced during the study and possible future areas of research.

Before moving on to the above-mentioned sections, I will go back to the first chapter and the research problems discussed there. Two sub-research problems were identified in the introductory chapter with the aim of studying the main research problem, focussing on the extent to which national institutions and sectoral characteristics affect the role of intermediary organisations. Previous chapters have provided extensive evidence that these two factors are indeed closely related to intermediary organisations. However, the results of this dissertation show that the scope of these two sub-research questions should be extended, since national institutions and sectoral characteristics affect not only the *role* of intermediaries but also their *emergence* and the *type* of intermediaries that emerge. In the case of the UK, we have seen how organisations like technology transfer offices are present in almost every university, thanks to government funding for third stream activities.

The concept of a European Paradox, which was noted in the introduction chapter, has been contested by scholars from innovation studies, who wrote that the problem was not one of translation but of weak research and industry (Pavitt 2001; Dosi et al. 2006). Findings from this dissertation provide support for those who are contesting the idea of a European Paradox. Particularly in the case of UK, but also in the case of Netherlands, there were complaints from both industry and university that the science base underlying agriculture was weakening, especially in regard to applied sciences. In the case of the UK, the lack of a strong industry was mentioned several times as a problem in a number of aspects, such as funding, uptake of research and so on. These findings show once more the shortcomings of viewing innovation as a linear process; it is not enough to focus on the translation, and it is also crucial to consider the larger system of innovation.

9.1 Contributions of the dissertation

In the introductory chapter, it was mentioned that this dissertation contributes both conceptually to the academic literature through a systemic study of intermediary organisations and also empirically by researching a field that has been less studied. In the following paragraphs I will further explain these contributions in the light of the findings of this dissertation.

As mentioned in the introductory chapter, the number of studies on particular types of intermediary organisations, such as technology transfer offices and science parks, are numerous. Such studies have contributed significantly to the understanding of how specific organisations like technology transfer organisations or science parks work, and under what conditions they perform better. Nevertheless, the detailed insight they provide on specific organisational forms due to their narrow focus also prevents these studies from providing an overarching view of intermediary organisations in general. Studies that take such an overarching view are more limited, particularly in relation to knowledge exchange between the different actors of the innovation system. As in this dissertation, these studies try to provide an overarching view of intermediary organisations for a particular sector (Mason & Wagner 1999), country (Howells 2006) or region (Wright et al. 2008).

This dissertation contributes to the understanding of intermediary organisations by presenting a conceptual framework that attempts to analyse intermediary organisations according to five simple functions. Furthermore, it presents a classification scheme for intermediary organisations according to their role in the knowledge exchange process. The five functions suggested were derived from a review of existing university-industry interactions channels discussed in the academic literature. By moving beyond numerous individual channels and grouping them into a number of categories based on functions, one creates the opportunity to explore new interaction channels that may have not been covered by studies focussing on individual interaction mechanisms.

Complementing the five functions is a classification scheme for intermediary organisations. Based on a review of the academic literature on generic and specific intermediary organisations, four types of intermediary organisations were suggested in chapter 3. The classification was based on the extent to which intermediary organisations were involved in knowledge exchange (ranging from passive transmission to active generation) and how were they organisationally related to the university and industry. A fifth type of intermediary was suggested following the analysis of the empirical data collected here.

A further conceptual contribution has been made by using the national systems of innovation framework for the analysis of a relatively understudied set of actors. Previous studies making use of the national systems of innovation framework have largely focused on firms, and also on universities, with relatively few focusing on intermediary organisations. By focusing on intermediary organisations, this dissertation has further illustrated the utility of systems of innovation framework and the important role of national institutions in particular.

Finally, the deconstruction of the sector through concepts drawn from the technological regimes literature (opportunities, cumulativeness and appropriability) and then linking it with the role of intermediary organisation represents another conceptual contribution, which also helps to generalise the findings of this dissertation to a certain extent. Sectoral taxonomies put forward in previous studies (e.g. Pavitt 1984; Marsili 2001) suggest that certain sectors can be grouped together. To give an example, based on the findings of this dissertation, it can be tentatively suggested that in sectors where appropriability conditions are weaker, transporter type intermediaries will have less importance, which will make other intermediary organisations relatively more important.

Empirically, this dissertation makes a contribution to knowledge by collecting and analysing original empirical data on a relatively understudied field. As introduced in the first chapter, a large number of studies on intermediary organisations focus on what can be described as 'traditional' high-tech sectors such as medical biotechnology, IT or more recently nanotechnology. By focusing on the agricultural biotechnology sector where high-tech applications are used but not primary, I have shown that technology transfer tools inspired by a limited number of financially lucrative fields may not work well in sectors where commercialisation opportunities are less and where industry may not be as well endowed. Furthermore, the study has shone a light on some alternative models for knowledge exchange such as sector-specific technology transfer organisations (PBL, Amaethon), market alternatives to diminishing public sector research organisations (Keygene), and large collaborative programmes with active industry involvement in knowledge generation (TTI-GG).

9.2 Policy implications

This dissertation was motivated by a disagreement observed between the policy tools aiming to enhance knowledge exchange from university to industry and the academic literature discussing these tools. In this section, I will discuss the possible policy implications emerging from this study, which can contribute to the solving of this disagreement.

'One size does not fit all'

Regarding the US model for funding science, Pavitt suggests that "any attempt to apply the original model in countries other than the USA should therefore carry the following mandatory health warning: "*To be used only very sparingly. Consult local practising scientists and users beforehand*" (Pavitt 2001: 775). While it is difficult to make an assertion that intermediary organisations such as technology transfer offices were taken from the US and applied to the UK, and less so to the Netherlands, it would not be completely wrong to suggest a degree of US influence. Furthermore, the 'mandatory health warning' should be taken seriously regardless of where it is taken from, and it can be extended beyond the case of countries and be applied to the case of sectors.

It has been shown in this dissertation that some of the more common intermediary organisations such as central university technology transfer offices had several disadvantages with respect to the agricultural biotechnology sector, these being associated with the characteristics of this sector. As has been discussed extensively, the nature of the sector in Europe has weaker appropriability conditions than sectors such as pharmaceuticals or countries like the US. The relatively less frequent opportunities for commercialisation do not allow university TTOs to build the necessary experience in this field. On the other hand, sectoral or decentralised technology transfer companies or units, like the PBI or decentralised units within Wageningen, presented more advantages for both industry and university members as they had more experience in this sector.

It is recommended here that for sectors like agricultural biotechnology, where opportunities for commercialisation are less frequent, universities should have the flexibility to outsource technology transfer activities to specialist companies or decentralised units with sector-specific experience. It can be argued that universities should determine the fields in which they have more frequent technology transfer activities and direct the involvement of their technology transfer units to these fields, while outsourcing the others. It should be noted that this is different from determining the scientific fields where they have expertise, given that these can include fields where knowledge exchange activities take place through other functions than commercialisation.

Near-market research

Comparison of the Netherlands and the UK has highlighted the problem of a lack of sufficient applied research in crop sciences in the case of UK. As mentioned during the interviews and previous chapters, UK plant science is considered to be excellent by many but it is notably weaker in crop science. The nature of the sector makes it necessary for the translation of basic research into more applied research, before it can be taken up by industry. In the UK this role has been historically carried out by public sector research organisations, many of which were privatised as a result of the UK government policies in the late 1980s. While the PROs in the Netherlands are undergoing certain changes such as amalgamation, there is still a substantial body of PROs that can conduct such applied research. This is complemented by the existence of large-scale collaborative programmes between university and industry where, in addition to conducting research, there is an element of training as well. Furthermore, the industry in the Netherlands has apparently overcome the weaknesses of PROs through developing strategic partnerships.

For overcoming the gaps left by the translation of basic research to applied research in the field of agriculture, two policy recommendations can be proposed. The first would be the establishment of programmes such as those in the

Netherlands (TTI-GG, CBSG) where the focus is on strategic research. There is already an initiative in this direction called the Crop Science Initiative, which should be supported long enough to enable it to address the needs of industry, especially considering the time it takes for crops to grow. The second recommendation would be the establishment of PRO-like structures that carry out translational research. Since it would be difficult to start from scratch, the best option appears to be to make use of existing institutions, which in this case are the John Innes Centre and more importantly Rothamsted Research. It was mentioned in previous chapters that it is already in the mission of Rothamsted Research to tackle industrial problems but that this is sometimes in conflict with the demands of the periodic Institute Assessment Exercise (IAE). The assessment criteria should perhaps be reconsidered to focus less on 'scientific excellence', allowing more flexibility for the institute to engage in industrial problems.

Demand-side policies

Innovation policies can be seen historically as the step following science and technology policies, and industrial policies. It has long been recognised in the literature and in policy circles that the focus should be on improving the performance of the innovation system as a whole, and that in order to do this one needs to have a diversity of policy tools rather than focusing simply on the supply or demand side only. However, it seems the focus may now have shifted too much towards the interaction between components of the system at the cost of the components themselves. To use a metaphor, it is not possible to have a chemical bond without atoms. In the case of agricultural biotechnology in the UK, one of the components, industry, has been weakening. Without the presence of a strong industry, the supply of excellent plant science cannot be taken up. It is therefore necessary to ensure that there is a strong enough industry that can make use of the research findings. This is particularly important in the case of the UK because of the research funding structure. As discussed in chapter 7, the share of general university funds have been declining over time, and universities are now expected to fund a significant part of their income through third stream activities. However, once again, this general goal does not take into account the differences across sectors, and in fields like agricultural biotechnology the possibilities for securing third stream income are much more difficult due to the lack of a strong industry.

Another option for the UK is to focus on certain other areas of research and to exclude agriculture. However, it is debatable whether this is a practical option, given that food security is a major concern for many countries including the UK.

Human Mobility

The interviews have highlighted the important role of skilled human resources at all levels for knowledge exchange between university and industry. Supporting the existing literature, interviewees from industry in both countries drew attention to fact that one of their largest resources is students and graduates in the field. In the UK, government-funded programmes such as LINK and CASE studentships were praised by industry, providing several benefits. While studentships exist in the Netherlands as well, a central funding programme was not mentioned although this could have been due to the limitations of the study. Companies mentioned that they do have internships that are funded internally. Nevertheless, based on the results of the data in hand, it can be suggested that the Netherlands at least consider the establishment of a central funding scheme for studentships, where students can spend part of their graduate studies within a firm. This can also be helpful in sectors where companies may not be able to afford to host an intern. This would not only allow knowledge exchange between university and industry but also help in overcoming the 'cultural' barriers between the two sectors.

In addition to the mobility of students, mobility of staff and professionals is an important policy area. The interviews showed that in the Netherlands mobility of professional staff was two-directional between university and industry. This means that as well as academics having secondments in industry, industry professionals had the opportunity of working as "0 professors" in universities. A similar two-directional flow was not observed in the case of the UK. Bearing in mind the limits of this study, it is recommended here that the UK labour laws and regulations should allow for greater two-directional mobility of academic and professional staff.

9.3 Limitations of the study

In this section I will discuss some of the limitations of this study and also provide the background for the next section on possible future areas of research.

One of the challenges of this dissertation has been the delimitation of the 'agricultural biotechnology' sector. As discussed in chapter 4, several databases were used to identify research-intensive companies working in the field of agricultural biotechnology. This includes some dedicated agricultural biotechnology companies, but mainly comprises companies working in the agrochemical and plant breeding industries. However, not all companies working in the agrochemical and plant breeding sectors conduct research in agricultural biotechnology, and therefore those that do not have not been included. Furthermore, some might argue that companies working in the food industry conduct research in agricultural biotechnology and therefore should have been included in the interviews. However, the food sector has been deliberately excluded from this dissertation because it would not be feasible to include such a large industry, given the time constraints of a doctoral thesis.

The delimitation of the cases to research-intensive companies in the agricultural biotechnology sector means that the results of this dissertation are based on medium and large size companies. Therefore the advantages or disadvantages of intermediary organisations may be somewhat different in other sectors that are populated with small firms.

The choice of interviews as the main method of collecting primary data comes with certain concerns as well. While we are confident that a reasonably representative set[68] of interviews was conducted for this study, the total number of interviews conducted is nevertheless limited. This is partially due to the relatively small population of the organisations conducting R&D in the agricultural biotechnology sector – as bounded within this dissertation – and partially due to the number of interviewees accessible. There may be further issues associated with the responses of the interviewees. In addition to limitations associated with interviewees' memories, questions may be misinterpreted by the interviewee or be

[68] As mentioned in section 4.3.1, case study methodology relies on theoretical sampling rather than statistical sampling.

unconsciously influenced by the researcher. While these problems cannot be eliminated completely, triangulation between the answers provided as well triangulation with secondary data lessens these concerns.

It has also been observed through the course of this study that there are countries like Spain where intermediary organisations such as science parks have been observed in the field of agricultural biotechnology. This can be related to the fact that in countries such as Spain, the regulations regarding field trials for genetically modified plants are more liberal, which may affect the size and strength of the industry. This can potentially affect the generalisation of the findings of this dissertation to other countries without first having a detailed understanding of their national institutions, even if they are located within the EU.

The interviews for this dissertation were conducted between Autumn 2006 and Summer 2008 in the UK and the Netherlands, which sets some limits for the findings and policy implications of the dissertation. By the time this dissertation was completed, changes were observed in the UK policy regarding the agricultural biotechnology sector. The Crop Improvement Research Club (CRIC) was set up by the BBSRC, Scottish Government and industry to bring research institutions and industry together to conduct research in selected crops (oilseed rape, barley and wheat) that would address the needs of crop production and other grand challenges such as food security and climate change. Many of the companies interviewed during the fieldwork have become members of CRIC. Other initiatives were also observed with the involvement of Technology Strategy Board, Knowledge Transfer Networks, industry, research institutions and universities during period between the end of fieldwork and completion of this dissertation. It is not possible to comment on the advantages and disadvantages of these initiatives or assess their structure in terms of the intermediary types, which remains as a limitation of the study but it also brings the opportunity to conduct further research in this area.

9.4 Future research

In this section, I will make some suggestions for future areas of research based on the previous section as well as on the findings of this dissertation.

It was argued in previous chapters that appropriability regimes both affect the role and the type of intermediaries. Within the field of agriculture, further research needs to be conducted within Europe and in USA. Conducting research in Europe would ensure that the appropriability conditions related to GM regulations would be similar. Field trial data from the European Commission show that, in contrast to the Netherlands and UK, countries such as Spain and France are more active in such trials, since these countries allow the growing of GM crops. It was also mentioned during the interviews that several companies working in this agricultural biotechnology have research stations in these countries. Conducting a similar research in these countries could generate further insights into how much the presence of industrial research affects the role of intermediary organisations.

The concepts drawn from the technological regimes literature (i.e. opportunities, cumulativeness and appropriability) can be further operationalised by developing additional indicators for each element. Such indicators might include patent numbers and patent-generated income for dealing with the appropriability conditions, or explicit questions about research agreements with universities for dealing with the opportunity conditions. A stronger conceptual framework can then be used to conduct surveys within the agricultural biotechnology field to test the results of this dissertation. Furthermore, the expansion of this research to other sectors that are research-intensive yet also understudied might help in further understanding the links between sectoral characteristics and intermediary organisations.

This dissertation has shown that although intermediary organisations are one of the most commonly utilised mechanisms for knowledge exchange, our knowledge about their roles and the conditions under which they offer advantages for knowledge exchange remains limited. By attempting to build a conceptual framework to provide a systemic understanding of the role of intermediary organisations and institutions, and to carry out research in a relatively understudied field (namely, agricultural biotechnology), this dissertation has attempted to fill an important gap in this literature. The weaknesses of the current dominant models of intermediaries that are discussed in this dissertation challenge policy makers to expand the diversity of the policy tools they employ.

The framework suggested in this study helps to expose the advantages and disadvantages not only of the more recognised types of intermediaries but also of the more novel types of intermediaries, contributing to the challenge of expansion mentioned above. If we are to be serious and sincere about enhancing the knowledge exchange between university and industry, not only for contributing to the economy in a few select sectors, but for contributing to society at large across all sectors, it will be necessary to generate new approaches to studying and understanding the nature of the sectors concerned as well as the nature of the participating actors in the broader system.

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APPENDIX 1: Sources and procedures used to determine firms working in the agricultural biotechnology field and conducting R&D

The case studies in both countries consist of interviews with actors that are involved in knowledge exchange between universities and industry. These can be grouped under the following categories: universities, companies, intermediary organisations and government bodies. In this section, we give an explanation of how the interviewees have been selected.

In order to determine the companies working in the agricultural biotechnology sector the following procedure was followed:

1) Several national and international sources were used to determine the names of the companies that might be working in the sector. The details of these sources are given later in the text.
2) After gathering a preliminary list of companies, their webpages were searched in order to see if they have any R&D activities in agricultural biotechnology field. It was necessary to perform this step in order to eliminate companies that are involved in activities which are not related to knowledge exchange in the area, such as distribution, instrumentation, machinery, financial and managerial services and so on. Furthermore companies that are only active in vegetable and flower seeds or environment have not been included in the list either.
3) The final list of companies includes those firms that are actively involved in some sort of knowledge activity within the agricultural biotechnology field.

The literature mentions several big players in the agricultural biotechnology sector (Shimoda 1998; Hayenga 1998). However, not all of these players are included in the list of companies to be interviewed. For a company to be included in the list, one of the conditions that must be fulfilled is to undertake R&D activity within the country of interest: the Netherlands or the UK. In some cases, large companies have only sales offices in these countries and on the asssumption that they are not engaged in active knowledge exchange, they have not been included in the list.

Nature Guide

http://guide.nature.com (last access: 08 November 2005)

The search was limited to those ones listed as Biotechnology Companies working in the field of "Agricultural, veterinary and environmental products and services" in the UK and in the Netherlands. The Nature Biotechnology Directory Website has been produced in association with Nature Publishing Group (publishers of Nature Biotechnology). Although there was not a certain definition of the methodology used for the formation of the directory, the website wrote"If you would like an entry on this site please visit the url below, complete the editorial questionnaire and press send", which suggests that entries were made by the companies themselves. This may possibly mean that there will be companies that are not listed there.

2001 Nature Biotechnology Directory

This directory of companies is published by the Nature Group and it is very similar to the Nature Guide. There is no information on how the information on the organisations is gathered, but considering the company information submission form at the end, it is likely that companies register themselves. The first part of the directory lists the companies that produce goods or services using a biotechnology process, or are involved in research in these areas. Of this list, companies were chosen whose area of application was listed as agriculture.

CORDIS Search

The Cordis database includes details of the projects financed wholly or partly from the budget of the European Communities. There have been specific programmes which funded research on biotechnology:

BEP: Biomolecular Research Programme, 1982-1986

BAP: Biotechnology Action Programme, 1985-1989

BRIDGE: Biotechnology Research for Innovation, Development and Growth in Europe, 1990-1994

BIOTECH 1: Biotechnology programme under FP 3, 1990-1994

BIOTECH 2: Biotechnology programme, under FP 4, 1994-1998

For BAP, BEP and BRIDGE programmes all the projects that included either a UK or NL organization have been scanned, and the companies that took part in projects related to agricultural biotechnology have been enlisted.

A further advanced research was carried out on the database with the following parameters:

Programme Type: Fourth Framework Programme and Fifth Framework programme (as they are already completed and both include projects related to agricultural biotechnology).

Programme Acronym: BIOTECH 1, BIOTECH 2, FAIR, LIFE 1, LIFE 2, LIFE 3

Contract Type: Cooperation Network Contracts, Cooperative Research Contracts, Joint Centre Research, Research Network Contracts and Thematic Network Contracts

Subject index: Agriculture and Biotechnology

Countries: Netherlands and United Kingdom

The projects whose Subprogramme area was listed as "Key action Food, Nutrition and Health" were ignored.

European Patent Office Search

http://ep.espacenet.com/

In the EPO database a preliminary search was carried out, by searching the names of the companies in the 2001 Nature Biotechnology guide, whose research area was listed as agriculture. The name of these companies were searched in the 'applicant' field of the EP database of patents. In order to include only the UK and the Dutch companies, the companies without the (NL) or (GB) abbreviation was not included in the results. To give an example; the company 'Alltech' has firms both in the US and in the UK. So 'Alltech Inc (US)' is not included in the results.

The European Classification System (ECLA) is an extension of the International Patent Classification (IPC) system. The classification symbol is made up of a letter denoting the IPC section followed by a two digit number denoting the IPC class. This might be followed by a sequence of a letter denoting the IPC subclass, a number (1-3 digits) denoting the IPC main group, a forward slash (/) and a number denoting the IPC subgroup.

As the aim of this search is to figure out the companies working in the general field of plant biotechnology rather than focusing on specific technologies, the IPC subgroup has not been taken into consideration. Of the listed IPC codes, 7 of them were clearly related to plant technology and these were chosen to make a search for the companies. Through entering these codes in the classification field and limiting the applicant firms to those in the UK and the NL, additional company names were obtained.

Bioproduct Database (www.bioproduct.info)

This database is a service of the Rothamsted Research and holds information about 500 organisations from different countries around the world. The information in the database is entered by the members.

The database was searched for four main "interest areas" believed to be directly related to the plant biotechnology: agrochemicals, alternative crops, crop types and plant breeding. The search was limited to the service of "contract research & development and laboratory analysis" in order to increase the possibility of finding organisations that actually either generate knowledge or take part in the exchange of it.

Agbiotechnet Database

http://www.agbiotechnet.com

AgBiotechNet is a service of the CABI publishing and it includes several links of which one is a list of major companies working in the field. Therefore the names of the companies in the UK and the Netherlands were noted.

LINK Projects Database

LINK programme is operated by the Office of Science and Technology of the UK government, and basically it aims to promote collaboration between business and research base. Therefore each of the projects must have at least one business partner. The list of collaborators includes those who are involved in the projects currently underway or recently completed (as of February 2004).

The following project acronyms were used for the search in the LINK projects database of collaborators.

AFQ	Agro Food Quality
CIMNFC	Competitive Industrial Materials From Non-Food Crops
CPM	Control of Plant Metabolism
CROPS	Crops for Industrial Use
HORT	Horticulture
SAPPIO	Sustainable Arable Production

Of the participants in the projects with the given acronyms, those that were listed as Large Enterprise or SME were selected. The list covers only companies from the UK due to the nature of the programme.

DEFRA

http://www2.defra.gov.uk/research/project_data/subject.asp?SCOPE=0

The DEFRA website provides information about projects that are ongoing and completed. Companies that took part in the projects in the following field were added to the preliminary list:

Arable Crops, Horticulture and Potatoes, Non-food Crops, Plant Genetic Resources, Plant Health, Plant Varieties and Seeds.

APPENDIX 2: Interview Guideline

[introduction]

1) Have you collaborated or worked with another organisation in order to access knowledge, skills and similar for innovation, over the last three years?

A) Yes
B) No (Proceed to 2)

2) What was your reason for not collaborating?

A) No reason to collaborate (proceed to 2A1)
B) Did not have any contacts
C) Did not have any financial resources
D) Bad past experience
E) Other

2A1) How do you access new knowledge?

3) Can you recall the frequency/number of these collaborations over the last three years?

A) One (proceed to 4)
B) A few (proceed to question 6)
C) A lot (proceed to question 7)

4) With which organisation was this collaboration with?

The answer can be an intermediary organisation or a university, and according to the answer the questions change

5) Can you give me a short description of this collaboration?

[In this question, I will see in which functional group the answer is included in. For example, if it is joint R&D, it will be in the function of 'easer access to knowledge base'.

A) Easier access to human resources
B) Easier access to knowledge base
C) Increased opportunities for commercialisation
D) Access to infrastructure
E) Increased access to networks

5.1) What were your aims for this collaboration?
5.2) Were you the one to initiate this collaboration?

a) yes, we were the one initiate this collaboration – *in this case, ask*
How did you contact the organisation?

b) no, we were appraoched by the other organisation – *in this case, ask* Do you know how and why the other organisation chose to contact you?

5.3) Can you briefly describe the short and long term benefits of this collaboration?

[*If not understood, level 2 question*: what did you get out of this collaboration?]

[*If not understood, more clarification*: did you gain knowledge, or have access to skilled human resources, increased networking and similar?]

5.4) As I have mentioned in the beginning, knowledge can come from different sources. What are some other channels you use for accessing knowledge? Do you have preferences for using one channel over the other for more specific reasons?

[*If not understood, level 2*: To give some examples, you can access knowledge through publications, joint projects, patents, conferences and so on. Which sort or source you tend to use more frequently for accessing knowledge for innovation]

5.5) When you compare these sources of knowledge with the collaboration you had, which one does it seem more beneficial to you?

** If the answer to question 4 was a university continue skip question 5.6*

5.6) Why have you preferred to collaborate with this organisation rather than collaborating with a university directly?

6) Can you recall with which organisations these collaborations with?

a) Universities

b) Intermediaries

c) Universities and intermediaries

6.1a,b) Can you give a brief description of these collaborations?

6.1b) Can you give a brief description of these collaborations, differentiating between organisations x,y,z (universities) and x,y,z (intermediaries)

** At this point, depending on the number of the collaborations, either I want to go through all of them, or focus on a few, trying to pick up examples from both universities/ intermediaries when possible.*

	Nature	Reason	Contact	Benefits
Case 1				
Case 2				
Case 3				

6.2a) *If the collaborations were only with universities*;

Have you considered collaborating with other organisations such as intermediaries?

If yes, why didn't you use it?

If no, why haven't you considered it?

6.2b) *If the collaborations were only with intermediaries*;

Have you considered collaborating with universities?

If yes, why didn't you use it?

If no, why haven't you considered it?

6.2c) *If the collaborations were both with universities and intermediaries, and if there was a a collaboration type (based on functions) which was carried out both by universities and intermediaries, I will ask to compare them to each other*

7) Over the last three years, what type of organisations did you collaborate with most commonly? Do you prefer to collaborate with different types of organisations for different channels of acquiring knowledge?

At this point, after getting a brief summary of activities, I will focus upon a few with the same idea in question 6 in general

8) In this question I want to present the interviewee with the list of functions and ask what sorts of channels besides universities and intermediaries they use for each functional category. Also, I want to ask the interviewee to rate the different channels according to the importance of acquiring knowledge for innovation.

1) Easier access to human resources
2) Easier access to knowledge base
3) Increased opportunities for commercialisation
4) Access to infrastructure

APPENDIX 3: Interview Demographics and Coding

Below is the distribution of interviewees across countries and institutions. Other includes organisations such as PROs, and sector associations and external intermediaries.

	Industry	University	Other	Total
UK	15	6	8	29
Netherlands	15	6	6	27
				56