SCIENCE • SEEDS • SYSTEMS

Innovating agricultural biotechnology in Argentina

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Front page photo taken by Mona Nedberg Østby, 2008

Soybean fields (Region of Santa Fe, Argentina)

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Mona Nedberg Østby

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1. INTRODUCTION

The widely commented *knowledge-based economy* features knowledge-intensive industries as the core of a new techno-economic paradigm. “Knowledge businesses” are thought to draw increasingly on networks and mutual strategic alliances (Dicken 2007), highlighting the importance of learning and dynamism for firms, regions and nations. Penrose (1995: xix, in Cooke and Leydesdorff 2006) affirms that “it is necessary for firms in related areas around the world to be closely in touch with developments in the research and innovation of firms in many centres”. Studies on technology and innovation show that the ability of a sector, region or nation to innovate and be ahead in the technology race is of major importance for economic growth. However, the mechanisms for access to new knowledge and technology are not unbiased, and Cooke and Leydesdorff (2006) emphasise that a new variety of “knowledge capitalism” increases inequalities both between and within countries. The biotechnology sector has proved to be one of the most knowledge intensive of industries, constituting a major driving force behind innovation activities. Furthermore, the industry displays a high degree of agglomeration and clustering, which has brought both scientists and policymakers to show interest in the role of spatial concentration, localised learning and networking. Biotechnology's leading role in technological advancement has also made many see it as a port of entry to the technology race. Gertler and Levitte (2005) suggest that biotechnology could lay the foundations for “a new technoeconomic paradigm”, by means of its diverse areas of use and its ability to combine other technologies. Similarly, Cooke (2006) proposes a new global economic geography based on knowledge domains, where biotechnology claims a lead role in innovation and research.

Thus, the scientific grounds and knowledge-intensity of biotechnology (*c.f.* its analytical knowledge base as proposed by Asheim *et al* 2007) merits closer studies in order to better understand how knowledge is produced and transferred. However, research on biotechnology should move beyond mere assessments of its technological characteristics and also consider its controversial aspects. Dicken (2007) notes the increasing importance of biotechnology in food production. Moreover, this trend relates to the shifting geography of the agro-food industries, as a handful of large transnational firms integrate and dominate the entire value chain. Morgan (2006: 7) emphasizes the distinct attributes of the food sector by scrutinising “the desire by industrial capitalists to 'outflank' the biological systems and to disembed food from a traditional regional cultural context of production and consumption”. It is exactly the recognition of the local embedment of agricultural production that renders seed biotechnology interesting. Studying biotechnology can therefore yield comprehension both for the dynamics of innovation processes in complex technologies, as well as the impacts for agricultural production. The economic potency of biotechnology and its potential ubiquitousness in agriculture also highlights the importance of examining the distinctive effects of agricultural biotechnology in different places, especially considering the changed role of agriculture. Being the world's second largest producer of genetically modified crops, Argentina comes forth as a compelling. Moreover, the key role of the agricultural sector in the country suggests that seed biotechnology is momentous for the economy as a whole. Fixing attention on Argentina also counterbalances the general emphasis on the West in innovation scholarship, opening up for new grasps of biotechnology dynamics in developing countries and regions.

1.1. Research questions

The objective of a study is articulated in the research questions proposed by the researcher, pointing to specific themes or problems of interest. The starting point of my project was an interest in the dynamics of innovation and technological change. As argued above, biotechnology is not only one of the most complex technologies today, but also an industry that touches on a wide array of societal aspects such as agriculture and food production, scientific milieus and corporate logics. In this context Argentina stands out as a particularly dynamic country, displaying rapid technological progress despite an unstable and complicated economic climate. The main topic for my research is accordingly: *How does new agricultural biotechnology emerge and diffuse in Argentina?*

Thagaard (2003) depicts the problem or research question as a *process* which is continuously revisited throughout the course of the research. Indeed, investigating Argentina's biotechnology sector has been an interactive process where the objective has both formed and been formed by the research process. This means that my conception of the theme has been significantly altered along with my enhanced understanding of agricultural biotechnology. The following research questions are a product of this, as public-private cooperation has revealed itself as particularly important in agro-biotech innovation:

How are the relations between public and private organisations constituted in Argentina's seed biotechnology sector?

The question builds on an appreciation of the different objectives and aims that prevail in the two sectors, suggesting that they fulfil complementary roles in knowledge production and innovation activities. In order to reach a full comprehension of the matter, I will first look into who the actors in biotechnology innovation in Argentina are. Mapping in this way the relevant actors also brings into focus the role of institutional reforms for technological change. The analysis therefore gives an account of the regulatory modifications that have been accomplished to facilitate the introduction of genetically modified organisms (GMOs) in the Argentine agriculture. This brings us to the second research question which seeks to grasp the background for collaboration between public and private entities:

Why are the relations structured this way?

The awareness of cross-sectoral relations and cooperation as creative for biotechnology development simultaneously justifies the theoretical framework chosen for this thesis. By conceiving of innovation as an evolutionary process, attention is directed at how actors and interests work together to produce and diffuse new technology. The innovation systems (IS) approaches provide a tool for studying this interplay and suggest that innovation and technological development is not a random outcome, but a complex process where knowledge emerges and translates into new products and processes (Edquist 1997). The concept of innovation systems was from the start linked to the national level. Applying national innovation systems (NIS) as a general theoretical framework facilitates an integrated analysis of the stages and processes of developing and transferring agricultural biotechnology, encompassing both national and sub-national levels. Furthermore, it highlights the role of national agents from the public as well as private sector, and also considers government policy implications.

1.2 Thesis structure

The research questions will be answered by presenting empirical findings from fieldwork and interviews with actors in Argentina's biotechnology sector. The analytical tools are collected from the theoretical framework constituted by NIS and related literature.

Chapter 2 discusses the methodological approach taken in the data collection. Here I present the rationale behind NIS as the main theoretical approach. The chapter also describes issues and events during the fieldwork. Chapter 3 focuses on the characteristics of biotechnology itself, and explains the most common techniques for genetic modification in Argentina and worldwide. These are important issues because the scientific basis of biotechnology has strong implications for innovation processes and relations between actors in the sector. I also give a short outline of the current situation of agriculture and biotechnology in Argentina.

The theoretical framework is elaborated in chapter 4. After a scrutiny of the NIS approach, I examine the workings of knowledge and flows for technological innovation. Asheim's (2007) concept of knowledge bases is then introduced, distinguishing between the varying innovation features of industries. This furthers a narrowing of the theoretical focus to the biotechnology domain, drawing also on more recent attempts to portray the changed roles of science and research milieus. A short presentation of intellectual property rights (IPR) then follows, before briefly considering biotechnology in the societal context. The key points from the theoretical review are summed up in an analytical framework, which also presents a model of the main actors in the Argentine biotechnology innovation system (figure 3). In total, these chapters provide the backdrop for analysing the innovation system of biotechnology in Argentina. Chapter 5 aims at an enhanced understanding of how biotechnological innovation takes place in the country. An outline of the regulatory framework is first provided, before the importance of IPR is discussed. The role of public sector research and development (R&D) is then analysed, revealing the discrepant position of the country's universities compared to the general literature on innovation. Then follows a discussion of the capabilities and strategies of private firms in the biotechnology sector, typified by the case of the local corporation Nidera. Also, a case of an emerging biotechnology research institute illustrates the importance of public-private collaboration to develop the industry. The last sections move beyond the conventional conception of biotechnology innovation as a product of mere science-industry interaction, and depict agricultural producers as central for the success of GMOs in the country. Lastly, chapter 6 offers some concluding remarks to the thesis, and opens up for new lines of study that could complement the contribution of my work.

2. THE RESEARCH PROCESS

This chapter presents the methodological basis for my research and gives an outline of the procedures used to obtain my data. I first give a brief account of my reasons for applying qualitative methods for data collection, and for choosing national innovation systems as a theoretical framework. Ensuing this, I argue for considering this research project as a *case*. I further discuss the main challenges linked to fieldwork and data collection, particularly concerning interviews in a foreign country. I finally conclude with an evaluation of my own work in light of the concepts of credibility and validity.

2.1 Theory and method intertwined

The objective of my research is to understand how new seed biotechnology develops and transfers between actors, and to assess how their relations within the innovation system affect these processes. The aim of the research, along with the researcher's philosophical standpoint, are the main determinants for which method is the most appropriate. A qualitative approach aims at providing a nuanced and context-centred analysis of a subject (Rubin & Rubin 2005). I therefore decided early to apply qualitative methods, with a focus on research interviews. This allowed me to study the role of biotechnology from different perspectives and obtain hands-on information from the agents involved in the processes of technology development and transfer.

The interest in complex relationships and structures as explanans for innovation and technological development was also the reason for employing NIS as the main theoretical framework. As will be elaborated in the following chapter, IS approaches focus on how technological innovation is generated through networks and systemic interaction between R&D users and producers. One the one hand this insight aided me in the preparation and accomplishment of the interviews. Conversely, the information gained from interviewees and personal observations of the R&D and agricultural sectors suggested that analysing biotechnology through the lens of NIS would be fruitful. Thus I decided to concentrate on IS literature as a theoretical basis.

2.2 Case and context

As pointed out by Yin (2003), case studies is only one of many possible approaches to social science research. Because it provides us with extensive knowledge about a bound phenomenon, the case study is generally suitable for answering “how” or “why” questions. It is also an applicable strategy when the researcher has limited control over events, and when the centre of interest is on present-day situations. These are indeed characteristics that fit my project; I have sought to understand how the different actors in the Argentine biotech sector interact. My influence has been confined to the specific interview situations, taking place outside the overall context of study. Finally, my focus is on the contemporary workings of the innovation system and my consideration of historical events relates to the evolutionary nature of technological development. It is furthermore important to acknowledge that prior circumstances influence a system and its actors and the context in which these function. This acknowledgement brings us to Yin's (2003: 13) definition of the case study, viewing it as 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". As will be shown in my discussion of the theoretical framework, an innovation system is by no means a clear-cut entity, thus the proposition by several scholars to divide into subsystems based on stages in the innovation process (Cooke 2002) or organisational logics (Kaufmann and Tödtling 2001). The topic for my study emerged from a dual curiosity about how new biotechnology is developed, and how it came to diffuse so rapidly in the Argentine agriculture. This led me to initially approach the field with more open-ended questions. Thus, relying on little existing knowledge and specific prior research on the topic, it may be termed an explorative study (Thagaard 2003).

It is in many ways sensible to conceive of my project as case study research. In broader terms, it is the case of a national innovation system. Narrowing down, it is the country's biotechnology sector which is studied, thus being a case of this particular technology. In order to illustrate some of the main points in the analysis, I further present smaller and more detailed cases – each constituting a "case within the case". This approach builds on a perception of case studies as valuable both inherently and as yielding knowledge also beyond the specific context. Hammersley and Gomm (2000) outline some basic features typical for case study research. First, it is common to concentrate on one or few cases. Accordingly, much in-depth information is gathered and analysed for each case. The case in question is further portrayed as naturally occurring, meaning that the researcher does not construct the unit of study. A qualitative approach to the data is also often preferred, and the main objective is generally to understand the particular case studied. However, some case studies also seek to make theoretical contributions or provide generalisable conclusions. Generalisations from case study research is much criticised, first and foremost for their unfitness to say something about entire populations of cases. However, Stake (2000) underlines that what is often needed is generalisation to the case in question or to a similar case, denoted as naturalistic generalisations. This builds upon an idea of the intrinsic case study, where the researcher's interest is in the case itself. These are valuable thoughts when applying the term 'case' to the Argentine biotechnology system, as the aim is not to make universal deductions about biotechnology or innovation systems. Rather, it is important to acknowledge that generalisations can be useful (and even necessary) to make broader statements about the case studied, and to draw on knowledge obtained in earlier research. I further believe that by providing thorough information about the situation in Argentina, the study can contribute to a more nuanced understanding of the nature of biotechnological innovation and the roles of the actors in the innovation system.

2.3 Entering the field and selecting informants

The analysis of innovation activities in Argentina's biotechnology sector is based on empirical data collected during extended fieldwork. The material was obtained mainly through qualitative interviews organised particularly for this research project. Altogether I conducted 15 research interviews lasting from about 40 minutes to 2 hours, where I was able to take my time and cover all topics in my interview guide. In addition I had a number of more unstructured conversations and discussions highly useful for my research. I have also learnt much from other sources such as lectures in both Argentina and Norway, documentaries and visits to farms and laboratories. The data collection was done in what was for me an unfamiliar country, and I did not know how I would cope with and be met in the Argentine context. Though I spoke Spanish well before arriving to Buenos Aires, the language barrier was obvious. This is partly why I preferred to do rather extensive fieldwork that resulted in a stay of seven months. Having extra time before starting the gathering of data allowed me to become accustomed to the Argentine context, take language classes and gain a better understanding of how the agricultural and biotechnology sectors were constituted. Being a stranger to the field presented me with several challenges, and I had do extra research and prepare well in order to understand the culture and particularly the biotechnology and agricultural sector. On the other hand, being an outsider also helped me grasp the core points I was interested in.

I had not established contact with any informants or persons that could be of help before leaving Norway. Starting from scratch meant for me a great deal of time and effort in order to find relevant companies, institutes and public offices. During the months before leaving Oslo I obtained an overview of the biotechnology and agricultural sectors, mainly through articles, reports and internet searching. Upon arrival I continued this work by reading newspapers, books and scientific material not available in Norway. I further listed the different agents that would be relevant to speak to and gathered contact information for institutions representing these. I came up with a list of agents including: domestic and international biotechnology companies, producers and farmer associations, public research institutions and universities, regulatory and government offices, intellectual property rights agents, and civil society and non-governmental organisations (NGOs). I was also open to include other parties in my selection if I considered it relevant during the course of the research.

I selected my informants based on strategic choice and accessibility. My selection can thus be categorised as strategic (Thagaard 2003), meaning that the persons I spoke to were contacted because of their particular position or function, or for their expertise on the subject. Furthermore, as a researcher I was not in a "pick-and-choose" situation and had to adjust to whom I achieved contact with and what information I received. I was prepared for difficulties in obtaining access toinformants, since a foreign female student is of little direct interest for companies and public institutions. Early in the process I found it difficult to even reach past the front desk, presenting myself as a social science student gathering information about agricultural biotechnology and interested in the work of the institution in question. In most cases I was asked to contact them at a later time, and on a few occasions I was asked to send a list of questions by e-mail. In every case I did, and despite follow-up e-mails and phone calls none of the persons or organisations responded.

All my initial contact efforts were towards companies and institutions in the capital Buenos Aires, as this is where most firms and organisations have their main office and where I myself was based. After continuous and rather unsuccessful attempts at obtaining interviews, thwarted by what many Argentinians informally termed the unfriendly "porteño"[1] attitude, I decided to redirect my focus to the city of Rosario. Rosario is considered the "agricultural capital" of Argentina, and the city where most important agents in the agricultural sector have a large or even their lead branch. Quite surprisingly I was able to organise several interviews by phone already before leaving, also establishing a first contact with other potential informants. During the four days I had in Rosario I managed to complete several valuable interviews and assist at an international seminar on biofuel. I also obtained a number of strategic contacts in Buenos Aires. One informant also facilitated entrance to the annual conference for the association for soybean producers[2], this year specifically on biotechnology. The procedure of getting in touch with new contacts through the means of other informants is known as the "snowball" method (Thagaard 2003). The danger is that the informants propose persons with similar characteristics and world views as themselves, limiting the selection and the researcher's access to diverse perspectives. I have avoided this by seeking informants from the different categories mentioned above, and by using a combination of personally selected individuals or agencies and the snowball method. Regardless of this, each informant represented different organisations and perspectives, and the method proved valuable to obtain access to many key informants. Interestingly, supporting both the strong network linkages in the biotech sector and the effectiveness of the snowball method, several informants proposed contact persons with whom I

1 Person from Buenos Aires

2 Buenos Aires, November 27 2007: "El futuro de la cadena de valor de la SOJA vista desde la biotecnología, la alimentación humana y la economía" (The future of the soybean value chain viewed from the sides of biotechnology, human nutrition and economy)

had already spoken.

2.4 The interview guide

My choice was to use a semi-structured interview guide with open-ended questions and a provisional set-up. This allowed me to lead the interview through all the topics that interested me, and at the same time open up for changes in the sequence, follow-up questions from my side or additional themes proposed by the informant. I tried to make the the interviews flow as naturally as possible by arranging the topics in a strategic order. First I gave a general presentation of myself and my work. I then encouraged the interviewee to give a short introduction of the organisation in question, before introducing more complex and detailed topics. In order to let the interviewee bring to the table any comments or questions before ending the interview, I always asked if he or she had anything to add. This also functioned as a corrective for my own interview guide. All in all, this gradual phaseout of the interview eased the shift to informal small-talk, avoiding awkwardness and preserving a good atmosphere between myself and the informant.

I initially prepared one interview guide for each sector I wanted to speak to, but I soon discovered that it was both possible and convenient to depart from a more general list of topics universal for all the informants. The list is included as Appendix 1. Because I did quite thorough preliminary research before each interview, I completed the broader interview guide with more detailed questions and complex issues according to the institution or person in question. Following this, larger parts of the interviews revolved around specific themes such as the organisation's research projects or lateral agreements. I found that open-ended interviews with a loosely structured guide, supplemented by more specific questions, was appropriate for my research interest.

The researcher always enters the research process with a predefined perception of the topic in question. In my case I soon became aware that my view on biotechnology was coloured by the Norwegian context, where both the legal framework and the public discourse are quite negative towards the use of agricultural biotechnology. This, however, is not the case in Argentina. I soon learned that concepts like “GMOs” and “transgenics” were not necessarily associated with “unnatural”, “unethical” and “dangerous”. On the contrary, this same vocabulary is widely employed by the industry promoting the technology. This also had implications for the preparation for and accomplishment of the interviews. Questions about public resistance, health and environment were initially cautiously approached without disclosing any of my personal opinions. Nevertheless, it seemed I had overestimated the controversy especially within the commercial sector, as most of my informants dismissed it as a minor issue and certainly not a problem. This experience also shed light on how my own conception of agricultural biotechnology could influence the investigation process.

2.5 The interview situation

All the interviews were carried out in Spanish. My informants were generally persons with higher education and extensive experience from the agricultural or biotechnology sectors and representing a firm, public office or research institution. In a country characterised by an unstable economy and where few have the privilege of higher education, my informants constituted in many ways an elite and a homogeneous group. Furthermore, many of my informants were chief executives or heads of departments within their organisation. The persons I interviewed were in other words highly educated, experienced and familiar with talking about their work. With this background there was a high risk of imbalance in the interview situation, due to my somewhat inferior position as younger, student and foreigner. I also expected to deal mainly with men, because of traditional gender roles in Argentina and the fact that most higher positions in both public and private sectors are occupied by men. However, many of my top end informants were in fact women. The gender distribution in the agricultural innovation system was quite surprising to me, particularly the fact that several of the private companies and associations I spoke to had female chief executives. During the informal conversations that often followed the interviews a couple of my informants actually commented on this, connecting the relatively high rate of female executives in the sector with its innovative and “modern” structure.

As mentioned I was well aware of the challenges and potential dangers of interviewing elites. It is furthermore important to see the researcher as an active part of the interview context rather than a neutral receiver of information, implying that the completion of the interview and the information obtained may be formed by the researcher. I therefore tried to be particularly conscious of how I presented myself and how I acted during the interview. When contacting potential informants I was careful to be clear concerning my position as a student, underling that any information woul be used purely for my master's thesis presented at the University of Oslo. It was further natural for me to address all the informants in a formal manner using the polite personal pronoun “Usted” (You in Spanish) and to show my gratitude for their time and information. On the one hand this served as a sign of respect on my side, at the same time as I wanted to preserve a formal distance in order for the informant to “take me seriously”. However, this was not always an obvious choice, especially with younger informants or with meetings in informal settings, and on several occasions I was encouraged to skip formalities and “tutear”[3]. There is a constant dialectical relationship between showing respect for the interviewee and assuring the researcher's status

[3] Informal way of addressing a person using the pronoun “tu” or “vos” (in Argentina)

position in order to maintain a balance in the interview situation. Although I never felt pejoratively treated, presenting myself in a proper manner was for me a way to compensate for my language inaccuracies, lack of expertise and young age. This also implied following the classic and formal dress code of the corporate and government sectors.

Apart from physical appearance and formal speaking codes I prepared myself well for each interview through learning basic facts about the organisation or person in question and formulating relevant and specific questions. This brings me to one of the major challenges of interviewing persons in high positions, especially in a different language and cultural setting than my own. Although I was clear on my position as a student on the "learning path", I felt the need to show that I had at least basic knowledge and competence on the subject, demonstrating that I had "done my homework". I found this important both for me as a researcher to maintain control of the interview situation, and for bringing discussions "to the next level", focusing on more complex and controversial issues. Nevertheless, I did experience "lecturing" from some informants that started to explain very basic concepts or lead the interview in their own direction. I dealt with this by posing in-depth questions or by introducing a new theme in a polite but firm way, thereby regaining control of the conversation.

2.5.1 Recording interviews

The majority of the interviews was recorded with a digital dictaphone/MP3 player. Recording the interviews digitally allowed me to obtain a complete transcript of all the information, also relieving me from the need to take extensive and accurate notes during the interviews. All transcripts and translations are my own. Because Spanish is not my maternal language I considered this important in order to avoid misunderstandings. Using a dictaphone is however not unproblematic, as some informants may be uncomfortable with such formal settings or having the information on tape (Thagaard 2003). I do not think the quality of the information was compromised, considering the relatively uncontroversial research topic and the fact that my informants in general were used to the interview situation. I specifically asked for permission to record each interview and all in all I never observed negative reactions from the informants. On the contrary many expressed perfect comprehension for my wish as a student and a foreigner to have the interviews on tape. It furthermore serves as a guarantee that the interviewer will get the information out correctly (Rubin & Rubin 2005).

On some occasions loud noise, transport or other disturbances did not allow me to record the interviews, and in a couple of situations I chose to rely simply on notes because it seemed highly unnatural to introduce a recorder in the setting. Rubin and Rubin (2005) note that recording frees time and energy during the interview to formulate relevant follow-up questions and note personal thoughts and comments on the topics discussed. Therefore, when unable to record, the researcher must pay extra close attention to everything said, also clearing up possible uncertainties right away. In my cases, taking notes required shorter pauses and moments of silence, perhaps allowing the informant to think through the topics or add relevant information. It is likely that some information from these interviews was lost or reduced in quality, because of my inability to note all details and important points. In order to compensate for this I wrote down general thoughts and personal comments directly after completing each interview, trying to mentally reconstruct the interview situation and the information given.

2.5.2 Informants and anonymity

The theme for my research has not been of a specifically sensitive character, and the data obtained does not contain intimate or personal details. As mentioned earlier none of the interviewees expressed disapproval or uncertainty regarding the taping of the interviews, and were therefore not particularly worried about discussing their work. However, I have chosen not to include the names of the persons I have spoken to but simply to mention the organisation they worked for. First, I consider names irrelevant for the analysis. Second, all my informants were assured that the data would be used only in the thesis submitted to the University of Oslo, something that might have induced some to speak or opine more openly that they would in other cases. However, many have shown interest in my study and requested a copy of my thesis, and avoiding naming therefore facilitates distribution also in Argentina. Thirdly, during the research process I have come to realise that relations between actors within the innovation system are fairly tight, and I am aware that many of my informants know each other. On the one hand this was how I gained access to several of them (the snowball effect), but I also discovered that a number of independent sources knew each other both professionally and personally. By excluding names I therefore avoid (to a certain degree) that informants mutually recognise each other.

2.6 Non-interview sources

The empirical data for this study has been collected mainly through interviews. However, I also gained a lot of valuable information from other sources and alternative media. I experienced that my relatively long fieldwork enhanced my understanding of the context and research theme, foremost by talking to people, reading newspapers and simply “being there”. It also allowed me to engage more actively in the specific field of agro biotechnology, referring particularly to informal conversations with experts, participation in seminars and conferences, and a three-day visit to a large farm doing GM (genetically modified) seed-multiplication for a multinational biotechnology company. During this latter stay I had the opportunity to follow three agronomists and workers through their daily routines and inspections of crops, allowing me to understand the farmer-side of the biotechnology issue. I accompanied the men in everything from administrative tasks and extensive field visits, to fruit picking and dinners with the family at the farm. I even participated in selecting cattle for sale to the dairy industry. When observing crops they explained the agronomical basics, such as particularities with the distinct species, differences between GM and non-GM crops, use of machinery and chemicals and soil and water management issues. I was introduced to concerns about production, commercialisation and technology, and learnt a lot from observing and participating in their day-to-day conversations and activities. In addition I was able to ask questions and propose themes for discussion, complementing the more general understanding for the production side with specific information and viewpoints on the farm's relations to other actors and why things were done the way they were. This focus group approach not only allowed me to learn about production techniques and gain field experience, but also observe the informants' discussions and hear their points of view in their everyday context.

During the seven months I spent in Argentina I had the opportunity of participating in several smaller lectures and meetings of relevance to my study. I also assisted at two one-day conferences in the cities of Rosario and Buenos Aires, as mentioned earlier. The conference audiences were composed mainly of representatives from the input (seeds and chemicals) industry, laboratory and research personnel, commercialisation agents and large scale producers. The themes centred around technical aspects, biotechnology in a national and global economy setting and food and environmental issues. After returning to Norway I also signed up for one lecture on biotechnology clusters at the Norwegian Research Council and a full-day conference on biotechnology at the Norwegian University of Life Sciences[4], something which both kept me updated and helped me mentally contrast the Norwegian with the Argentine context. In general, the lectures and discussions during the conferences provided me with much information of good value.

2.7 Credibility and validity

The concepts of *credibility* and *validity* are commonly used to discuss the quality of research. The credibility of a research project depends on the degree to which the data collection has been conducted in a satisfactory manner. Whereas positivistic traditions aspire to neutrality towards the object of research, constructivist approaches emphasise that the researcher herself is active in the field and thus affects the study material. According to Thagaard (2003), the notion of objectivity becomes invalid when the data results from interaction between the researcher and other

[4] Universitetet for Miljø og Biovitenskap (UMB), Ås, Norway

individuals. Thus, it is critical that the researcher clarifies how the material has been developed and evaluates the quality of it. Kvale (1997), employing the term *reliability,* underlines that the consistency of the findings is challenged along several stages of the research, from the interview situation to the analysis. My approach to the field has been to acknowledge that the data collection necessarily is influenced by my actions and preconceptions. The previous sections account for my strategies for elaborating material and discuss the main challenges I met during the process. I believe that I have preserved the credibility of my research by conducting a structured and consistent collection of material, for instance by employing a strategic but sufficiently diverse selection of informants and by recording most of the interviews. Furthermore, I have sought to be clear on the choices and interpretations I have made along the course of the research. Most importantly, being aware that complete objectivity is neither possible nor desirable, I have tried to maintain some distance to the field in order to perceive the complexity of the issue when analysing the material.

Validity within qualitative research can be understood as the degree to which the material and observations accord with the objectives of the research (Kvale 1997). Thus, the author states, the researcher must continuously check, question and interpret the findings. In order to ensure that I obtained the data needed to answer my research questions and interests, I constantly reviewed both the research objective and my methods to collect and analyse data, as accounted for earlier. Thagaard (2003) relates validity, or *confirmability,* to the *interpretation* of the results. This implies on the one hand that the researcher maintains a critical perspective on her own research and analysis. On the other hand, the validity depends on the support found in other research. Confirming in this sense the findings is contingent upon an adequate record of the foundation of the study. Finding support in earlier research is by no means a straightforward task, considering the relatively short history of agro biotechnology in Argentina. Another factor is that existing research can be difficult to access. Furthermore, although being a well-employed theoretical approach, most scholarship on innovation systems is confined to the European or North-American contexts. However, I believe to have found much support for my findings by drawing on various sources and scholars. I also hope that new combinations of theory and theme of study can provide a better understanding of the seed biotechnology sector in Argentina, and give some nuanced contributions to the IS approaches. These issues are related to the *transferability* of a research project, a notion that will be further discussed in the concluding chapter.

3. BACKGROUND

This chapter provides a basic introduction to the technical aspects of biotechnology and the most common forms in agricultural usage. Not only do I consider this important in order to achieve a clearer view of the theme of study. It is also deemed crucial for any comprehensive analysis of how innovation works. The varying mechanisms for technological advance across industries have spawned many studies and lines of research to focus on sectoral differences. As stated by Malerba (2005: 381):

> "...sectors differ in terms of knowledge base, the actors involved in innovation, the links and relationships among actors, and the relevant institutions, and (...) these dimensions clearly matter for understanding and explaining innovation and its differences across sectors."

As we shall see, the direct reliance upon scientific knowledge makes biotechnology a highly capital and knowledge-intensive industry. Its advanced features and dependence on laboratory work is also the outset for controversies on the subject, concerning issues such as corporate dominance in the food chain (Paul and Steinbrecher 2003), technological dependency among small scale farmers (Shiva 2000), and environmental problems (*e.g.* Raybould 1999; Pengue 2001; Lyson 2002). The chapter also gives a short outline of the R&D situation in Argentina and its implications for studying innovation and innovation systems in the country. An overview of the position of biotechnology in the agricultural sector then follows. In total, these sections amount to a basic background for understanding innovation systems and biotechnology in Argentina.

3.1 Genetically modified organisms

Traditional biotechnology encompasses the use of living organisms for utility purposes, including the use of microorganisms in fermentation, the crossing of plant varieties and animal breeding (Muñoz de Malajovich 2006). When speaking of biotechnology and controversies around it, one is generally referring to modern techniques where the heritage structure is altered through genetic manipulation. The focal point of this study is this advanced form of technology, more specifically *genetically modified organisms* (GMOs). GMOs in innovation systems are interesting to study due to the intrinsic features of the technology itself; departing from an analytical and highly advanced scientific knowledge base it requires a certain level of know-how as well as large capital investments. Activists such as Vandana Shiva (2000) have equated seed biotechnology with modern colonialism, viewing it as a mechanism enabling global corporations to control small-scale farmers in developing countries through creating dependence on their products and patenting indigenous and traditional knowledge. Other authors have also promoted biotechnology as something of a paradigm-shifting technology, constituting an innovation and research-driving force that other industries seek to match (Cooke 2006).

3.1.1 Genetic engineering

Genetic engineering (GE) refers to the technology of recombinant DNA[5], also known as genetic manipulation or modification, cloning or new genetics. Recombinant DNA technology involves inserting one gene or a set of genes from one organism in another, within or across species boundaries. Thus it is possible to combine DNA molecules from different sources in order to obtain organisms with entirely new properties (Muñoz de Malajovich 2006). Genetic engineering entails moving parts of the plant production process from the field to the laboratory, constituting a major source of dispute over scientific and ethical concerns. At the core lies the issue of GE as opposed to traditional breeding techniques, where strategic crossing of varieties or specimens is used to develop certain plant traits. In breeding, individuals of the same or closely related species are fertilised, and the genes themselves cannot be altered. Rather, selective parenting/mating ensures the enhancement and reproduction of desired characteristics. In contrast, GE employs mechanical, chemical or bacterial techniques instead of sexual reproduction to transfer genetic material into an organism. GE can as a result drastically reduce the timespan that traditional methods require for bringing out particular traits in a plant variety, and even design new combinations hitherto unavailable. There is accordingly a dichotomy between seeing GE as merely an advanced form of breeding, or as a fundamental "tangling" with nature.

My aim is not to provide a full discussion of the ethical aspects of biotechnology and GMOs. However, understanding the technology is crucial for any study of innovation and technology in society. Not least, our conception of modern biotechnology provides the basis for discourses concerning the existence, development and use of GMOs in agriculture. A debate over principles creates a dichotomy between "artificial" design of organisms and "natural" reproduction, regarding genetic engineering as fundamentally different from traditional breeding techniques. A number of grassroots movements, NGOs and religious communities demand strict regulation and even bans on GMOs on these foundations, also stating that many long-term and potentially adverse effects on human health and the environment are unknown. Conversely, private industry and promoters of biotechnology advocate GE as a form of breeding, making it possible to reduce the lead time between the initiation of the process and bringing about the new product. In order to discuss how the development and spread of biotechnology takes place, it is necessary to consider its technical aspects and inherent knowledge dynamics. Thus, what I study is technological innovation. However, I consider it important to reflect also on technology's interaction with society, as

5 Deoxyribonucleic acid

controversies both arise from and affect technological advancement.

3.1.2 Herbicide tolerance and pest resistance

The most common techniques for genetic manipulation are plants containing genes for herbicide and pest resistance, respectively. These are both part of the “first generation” GM crops, with features mostly of relevance to the producer. Correspondingly, the second wave of GM technology entails more consumer-oriented plant modifications, such as improved nutritional value, reduced allergenicity or altering of crop characteristics for industrial purposes (*e.g.* oil for biofuel)(Muñoz de Malajovich 2006). Planting seeds with inherent tolerance to a specific herbicide facilitates effective application of chemicals without damaging the crop. This has restructured the seed- and chemicals industries and paved the way for a strengthening and integration of large agro corporations, exemplified by Monsanto's 'Roundup Ready' seed technology that was developed to tolerate their own herbicide Roundup. Regarding pest resistant crops, included in the most severe criticism is the fear of accelerating resistance in insects and thus the development of new and more aggressive pests and diseases.

According to Slater *et al* (2003), there are a number of scientific as well as commercial reasons for the early focus on herbicide-resistant crops. First, necessary knowledge about the functioning of some chemicals was already in place; second, genes and biological resources for resistance were available from several sources; and third, techniques for the introduction of a single resistant gene in a plant were rather uncomplicated. This strong potential created by science was furthermore supported by the large interest from private industries, particularly agrochemicals manufacturers, in developing herbicide-resistant crops. In 2007 85% of the global sales of pesticides was managed by the six transnationals Syngenta, Bayer, Monsanto, Basf, Dow and Dupont[6]. Because weeds cause substantial damage on yields worldwide, tackling such stress is a major priority in modern agriculture. The use of herbicides that control several weeds at a time is among the most efficient methods, but can only be applied when the crop plant is not endangered. The obvious advantage of genetic modification lies in facilitating this. However, Slater *et al* (2003) underline that herbicide resistance is not strictly confined to GM technology, as this may also appear through mutation and natural selection (though less specific and at a lower pace).

The authors also conduct an environmental assessment of technology for herbicide resistance, beginning with the reasons for its wide adoption and persisting popularity. Of total US soybean production, the percentage of herbicide-resistant crops increased from 17 in 1997 to 68 in 2001. Similarly, in Argentina the numbers for GM crops of total soybean production were in 1997 less than 30%, rising to 90% in 2001. In 2007 the proportion of GM (herbicide-resistant) versus

[6] http://www.transnationale.org/companies/basf.php, 21 August 2008

conventional soybean crops was 99% (James 2008). Although the massive spread of herbicide-resistant GM soybean was accompanied by a sharp rise in the use of glyphosate (*e.g.* Roundup), the total use of herbicides has been argued to decrease because glyphosate[7] replaces other less efficient (and occasionally more environmentally adverse) chemicals. The main beneficiary is thus the farmer, who despite the higher price of the GM technology (Roundup Ready) has a net reduction in input costs (Slater *et al* 2003). Nevertheless, a persistent danger from increased use of GMOs is the development of “super weeds” that display resistance against the most common herbicides. One argues that two factors may start such a trajectory. On the one hand GM crops stimulate the repeated application of one herbicide, on the other the resistant gene may be transferred from the crop plant to the weed ('gene flow'). Transgenes may disseminate from modified crops to non-GM varieties of the same species, and hybridise with other crop or weed species. Gene flow may occur temporally through seed banks or spatially through the spread of seed and pollen, thereby causing contamination within a field or over larger, unintended areas (Raybould 1999).

Pests are estimated to cause loss of about 13% percent of the world’s potential crop yield, slightly more than yield losses due to weeds. Modern agriculture has aggravated the problem because intensive practices and monocultures allow pests to build up over years, again fomenting dependence on chemicals. A continuous spiral of new pesticides as a response to pests developing resistance against chemicals is then initiated. Accordingly, new insect-resistant crops are hoped to simultaneously reduce insect damage and reliance on agrochemicals. The most common technique for insect resistance through genetic modification is using genes from *Bacillus thuringiensis* (Bt). This bacteria was early found to adversely affect insect larvae by producing toxic proteins, and by introducing the gene coding for Bt proteins into seeds, plants produce their own pest toxins. Bt has for the last 50 years also been used as a “biopesticide”, though such surface application has proved less effective regarding perforation of plants and surfaces. The experience of “safe use” of the bacteria has nevertheless facilitated the development of GM technology using Bt. In order to be effective against liable insect pests the gene must produce a sufficient amount of a certain protein in the plant, requiring substantial modification. Furthermore, because the proteins in question are so specific in targeting pests, using different transgenes coding for different proteins, resistance against particular pests according to each crop can be created (Slater *et al* 2003).

As mentioned, one of the major dangers of the technology is the speed at which target pests can develop resistance to Bt. Monocultures and continuous planting of Bt crops within an area can exacerbate the problem, and according to Slater *et al* (2003) Bt-resistant pests may arise over only a few generations. There is also concern about other environmental problems related to the use of Bt,

[7] Molecule known for effectively exterminating a broad range of plants. Glyphosate was first commercialised by Monsanto as the herbicide Roundup, but the patent expired in 2000.

like contamination of non-GM crops. This debate was spurred by the US approval to grow Bt maize for animal feed even though the crop had been determined unsuitable for human consumption due to possible allergenicity. When traces of the corn was found in Kraft Foods taco shells in 2000, a number of maize products were immediately removed from the market. Furthermore, toxicity to non-target insects is another fear, exemplified by a 1999 report suggesting that pollen from Bt maize could adversely affect Monarch butterfly larvae. Although there are few proofs of environmental or health problems connected to GM crops, these cases underline the need for more thorough risk assessments and add to the controversies around the technology.

3.2 Biotechnology in Argentina

It is the two above-mentioned techniques for genetic modification that dominate agri-biotech worldwide. The global distribution of GMOs according to characteristics is as follows: 63% herbicide tolerance (soybean, maize, canola, cotton, alfalfa), 18% Bt (maize, cotton), 19% combination herbicide-tolerant/Bt (maize, cotton). In Argentina, the parallel numbers for 2007 were 83% herbicide tolerant soybean and 13% Bt maize, being the two main GM crops (James 2008). Herbicide tolerance and insect resistance are characteristics belonging to the so-called “first generation” biotechnology, being of value mainly to the farmer as it facilitates production and lowers input costs. The crop as a product does, however, not display any apparent traits different from conventional ones, and is hence not of specific advantage to the consumer. Figure 1 illustrates the evolution of soybean and maize in the Argentine agriculture in terms of land use. The sharp rise particularly of soybean cultivation is clearly related to the the economic advantages for the farmer.

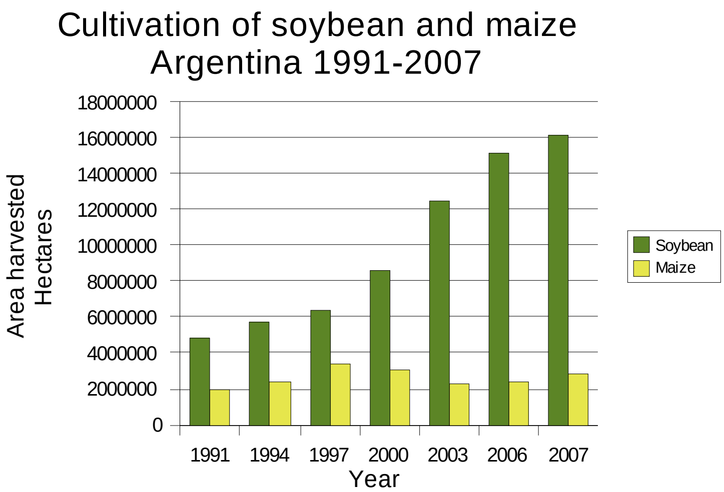

Figure 1: Cultivated area of soybean and maize
Source: FAO statistics (Faostat) 2008

Different varieties of soybean and maize are by large the most important GM crops in Argentina. GM soy has had a more profound impact both economically and in terms of cultivated area, and the total benefit accumulated between 1996 and 2005 is estimated to nearly USD 20.000 million. The equivalent for maize is about USD 482 million. The distribution of the benefits between the actors within the two sectors is, however, visibly diverging, as the producers take the main share (78%) of the surplus generated by transgenic soybean. In the maize sector 43% and 41% of the benefits is portioned out to the producers and the technology providers, respectively, leaving the nation state with approximately 16% (Trigo and Cap 2006).

3.3 The research system in Argentina

A general characteristic of the literature on innovation systems is the overall focus on Europe and North America (USA and Canada). When applying the framework to other countries it is therefore necessary to consider the wider socio-economic differences that may challenge the smooth transfer of the framework, especially regarding power relations. As Miettinen (2002) argues, policymakers in OECD[8] countries have been heavily involved in developing the NIS approach. In this sense the framework reflects the "Western" context, for instance in reviewing the role of publicly financed physical and knowledge infrastructures in innovation. It is underlined that firms operate within frameworks of regulation, culture and values, where institutional set-up and public policy "shapes firms' economic performance and the macroeconomic evolution of the economy as a whole" (Smith 1997: 90). Knowledge infrastructure is outlined as most important for economic (industrial) activities, and it is argued that the public sector is crucial in constructing this:

> "The scale, monopoly and externality aspects of infrastructure mean that in practice the private sector often lacks either the incentives or the financial capability to construct infrastructure; it is frequently very much a matter for public decision-making."
>
> (Smith 1997: 93)

The author further states that government spending on R&D in OECD countries "typically" lies at about 1% of national income. In Argentina, the share of the gross domestic product (GDP) annually spent on R&D varied in the period 1996-2005 between 0,39 and 0.45%, about 65-70% of this deriving from government sources[9]. In the previous years, between 1990 and 1996, the country's R&D expenditures suffered a dramatic decline of 35%[10], highlighting the instability of the sector.

The volatility of the economy is likely to affect not only the performance of the R&D system, but also the roles of the actors involved. When public investments are seen as highly

8 Organisation for Economic Co-operation and Development
9 http://www.ricyt.org, 12 August 2008
10 http://www.nsf.gov/statistics/nsf00316/secta.htm#fig1, 12 August 2008

unreliable, alternative sources of finance are sought, foremost of foreign and private character. Concomitantly, numbers show that R&D investments to Argentina by US-based private companies increased threefold from 1990 to USD 42 billion in 1996[11]. When applying the NIS approach to my case these disparities must be considered, because they shape the capacities of and relations between the actors in the system.

3.4 The agricultural sector

According to Trigo and Cap (2006), the agricultural sector is one of the most dynamic of the Argentine economy, currently constituting about 30% of GDP. Although numbers have been pointing upwards since the 1970s, agricultural production has experienced a particularly high growth in the period after 1996, when the first variety of GM soy was introduced. The area of cultivated land increased steadily from around 20 million hectares in 1991 to nearly 30 million in 2005. Output in terms of tonnes produced more than doubled from 38 million to over 80 million during the same period, the most significant leap occurring between 1996 and 1998. Figure 2 provides an overview of the increase in total hectares planted and tonnes produced between 1990 and 2005.

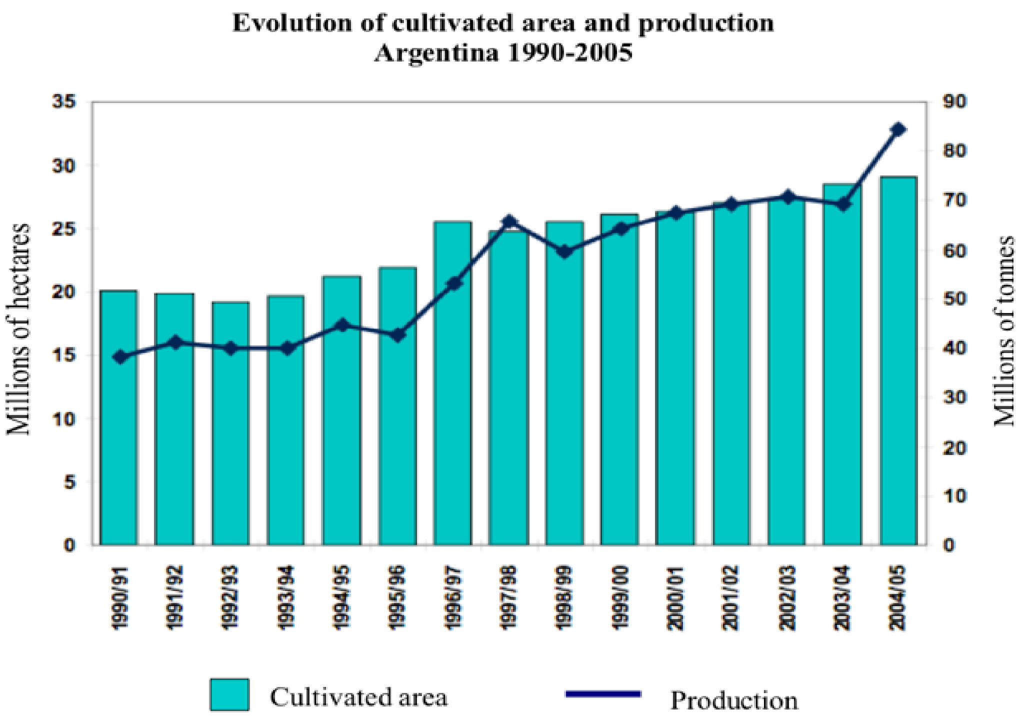

Figure 2: Area of cultivation and production

Source: Trigo and Cap 2006

[11] http://www.nsf.gov/statistics/nsf00316/secta.htm#fig1, 12 August 2008

Exports, first and foremost of grain (wheat and maize), oilseeds (soybeans) and oil, also rose substantially along with increased productivity. This is linked both to rising investments in infrastructure for value-added activities (depots, processing equipment, harbours) and to foreign capital investments. In addition, the sector experienced a notable process of mergers and acquisitions (M&As) of firms. Varela and Bisang (2006: 227) denote these processes as a new agricultural model that restructures relations and knowledge networks in the sector. Arguably, modern biotechnology has created a “world-wide oligopoly composed of very few agri-biotechnological mega-corporations”. Because of the particularly high knowledge- and capital intensity of the technology, already large-scale enterprises strengthen their position through M&As of other seed and research firms. Between 1996 and 2004 the six global dominating agro-corporations (Monsanto, Syngenta, Dupont, Bayer Crop Science, Dow Agroscience, Basf) acquired around 50 smaller firms, giving them a 100% control over the transgenic seed market and a substantial part of the agrochemical and seed markets in general. Relating this situation to Argentina, the authors find that local biotech activities evolve in the shadow of these transnationals. When R&D is clustered into large corporations, national agents are confined to using and adapting new biotechnology. The linkages between global players and local agriculture are in Varela and Bisang's view worth scrutinising. In fact, the current high growth rate of agriculture is indicated to be an incentivising factor for corporate collaboration with local actors, as these take the role of transfer agents for externally developed technology. These issues are discussed in chapter 5.

4. BIOTECHNOLOGY AND INNOVATION IN SYSTEMS

This chapter presents the theoretical framework for analysing biotechnology innovation in Argentina. The main point of departure is the national innovation systems (NIS) approaches, which consider innovation and technological change in light of the system set-up and relations between the actors involved. A review of NIS scholarship is first provided, problematising each of the notion's elements. The concepts of knowledge and knowledge bases are then explored. Acknowledging biotechnology as building on an analytical knowledge base surfaces as important to grasp the mechanisms of innovation and interaction between system participants. Following this, a clear conception of science and systems is presented, leading up to a discussion about biotechnology innovation in a systems perspective.

4.1 Decomposing National Innovation Systems

The importance of technological change and innovation for economic growth has received increased attention over the last century and decades. Since the early 1990s much literature has focused on the systemic nature of innovation. Miettinen (2002) outlines two basic origins for the emergence of the national innovation system approach. Firstly, there was the aim to explain the varying growth rates and technological gaps between countries. Secondly, referring to Lundvall (1992), the national innovation system constituted a break with neoclassical economics, redirecting focus from resource accumulation to learning and innovation as the foundation for economic prosperity. As pointed out by Amin and Cohendet (2005: 468), the integration of territoriality in innovation studies “compensates for the blindness in mainstream economics towards space in accounting for economic behaviour and knowledge formation”. The complexity and interactivity of innovation generation forged new perspectives on how innovation occurs and which role it plays in the economy. Continuous interaction between a number of actors along the entire set of stages underline the evolutionary character of innovation processes and shows that a firm or an organisation does not innovate in isolation (Edquist 1997). National attributes were further found to influence technological systems and thus development (Dicken 2007). From this emerges the conceptual framework of national innovation systems.

Studying innovation from a systems perspective departs from this interactive understanding of innovation. The “systems” concept may also be tricky to define, exemplified by Edquist's (1997: 15) holistic view of a “system as including all important determinants of innovation”. It therefore refers to a group of actors or activities, much like a network, but a system is normally characterised by a firmer structure and with a longer timespan (Fagerberg 2005). Miettinen (2002) directs attention to the vagueness of the concept, arguing that NIS approaches take little use of systems theory, the theory of technological systems or other attempts at theorising on systems. Referring to the outline by Niosi *et al* (1993, in Miettinen 2002) of NIS as a network of institutions, he argues that recent studies of innovation and learning draw on such network thinking rather than a systems concept, because an interactive and evolutionary perception of innovation does not necessarily lead to a notion of systems. Furthermore, available systems theories do not integrate cultural specificities and therefore run the risk of overlooking the importance of technological artefacts that interplay with the more abstract components of institutions and structures. As an alternative to systems approaches, Miettinen therefore proposes to study innovation through other lenses such as network studies, sociology of economy, science and technology, cultural psychology and learning theories. However, Edquist (2005) does give a short outline of the "system" notion according to general systems theory. First, a system is constituted by its components as well as by the relations between them. Second, a system has an objective or a function. Third, the system has limits that distinguish it from "the rest of the world", something which is fundamental for any empirical studies of it. How encompassing an innovation system should be, is nevertheless a matter for discussion. A national innovation system can be defined both in a wide manner including all parties involved in processes of knowledge enhancement and learning, and in a more narrow sense limiting the system to entities such as R&D organisations, universities and technology institutes (Lundvall 1992). In the comparative study edited by Nelson (1993), the authors base themselves upon an open view of innovation focusing on performance and the dynamic aspect. Consequently, the concept of innovation system was hard to define, and the study rather aspired to experiment around the issue and shed light on the field. The point of departure was nevertheless that it was still relevant to study the systemic nature of innovation in order to grasp the complexity of the process. Focus was also kept at the national level, although noting that a more thorough analysis of the effects of internationalisation was needed.

The debate around the nation as the level of analysis is partly fuelled by studies of globalisation and transnationalisation of production, commerce and innovation, as well as by increased focus on sub-national levels such as regionalisation processes. In the face of increased cross-national interconnectedness, national divergence in technological systems and capacity is still of high relevance (Dicken 2007). Lundvall (1992) outlines two dimensions related to the nation state as a prerequisite for a national system of innovation. First there is nation as an expression for a shared culture. Second, there is nation as a geographically bounded area governed by a central state authority. The ideal is a nation state where the two dimensions correspond perfectly, although few countries meet these requirements. Nevertheless, Lundvall states, knowledge exchange and learning is facilitated within a national environment where actors share norms and experience, particularly when dealing with tacit knowledge which is difficult to codify. Polanyi's workings on the tacit dimension of knowledge relates to the fact that “we know more than we can tell”, and that some forms of knowledge can only be transferred through personal contact, trust and experience. Lundvall (1992) revises the neoclassical perception of markets as constituted by rational actors in anonymous relationships, where national borders of culture and institutional set-up are seen as insignificant. Contrary to this, studying national systems makes sense because markets are organised differently within them, according to varieties in governance, rules and norms. The interactivity and complexity of innovation processes is based upon communication and cooperation, something which is difficult across cultural borders. The nation, viewed above as a cultural entity, may thus be an appropriate level for studying innovation in systems. Furthermore, applying a systems approach to the national level also provides a foundation upon which public policies to stimulate innovation can build (Lundvall *et al* 2002). Actually, the fact that policy-makers have been fast in adopting ideas and concepts from NIS literature is held as an argument for further developing its theoretical basis. Interestingly though, this influence may go both ways. The NIS approach has mainly been developed with regard to the Western context, and as mentioned, OECD and EU[12] officials have been heavily involved in formulating language and terms for technology and innovation policy (Miettinen 2002). Accordingly, exporting the term as a universal framework within which technology policy can be formulated may prove to be problematic in light of varying institutional capabilities.

Recent studies on innovation systems have tended to shift focus to the regional level. Emerging from research on regional networks of firms and industrial districts and Michael Porter's cluster concept, as well as the downsizing of the national innovation systems approach, region-based policies were considered crucial for stimulating technological development and competitiveness. Lundvall *et al* (2002) consider the focus on *national* systems controversial in light of globalisation processes that put pressure on the nation state. Nevertheless, they point to the fact that the national level still plays an important role for some innovation activities, and studies show that the provenance of multinational corporations (MNCs) does affect their behaviour. In place of regarding the national innovation systems approach as an alternative to the more recent focus on regional, technological or sectoral systems, the authors underline that conducting analyses on the national level allows integration of the policy aspect. Other spatial levels or sectoral approaches may also give important contributions to our understanding of national constraints, workings on the regional level, and the role of cross-national and supranational cooperation in innovation processes. Accordingly, this study applies the NIS as a ground framework, also considering processes on the global and regional scales to reach an aggregate and informed analysis.

[12] European Union

4.2 NIS between science and politics

The innovation systems framework seeks to highlight the systemic nature of innovation, a process determined by the relations between the system's participant actors (Godin 2007). As discussed, what a national innovation system comprises is, however, not always clear. In fact, the fuzziness of the concept is perhaps one of its major weaknesses. It is furthermore continuously underlined that the concept of innovation systems does not aspire to a theory. Rather, it must be considered an approach, a perspective through which innovation and technology can be studied. The concept was first developed by Freeman (see Freeman 1987), Lundvall (1992) and Nelson (1993), applying it to the national scale. In the words of Edquist and Lundvall (1993) the national system of innovation is made up by institutions and economic structures working with technological change, that is, the system of research and development (R&D) and institutions related to technology's impact on economic growth.

The NIS constitutes a framework for studying technological development. Because the formulation of the framework influences our perception of technological change, a comprehensive analysis must also acknowledge the background of it. The NIS approach has since its launch received much attention both from academic environments and policymakers. This can be attributed to the term's broad spectrum of employment potentials, but it also raises a number of challenges. It is worth looking into how the innovation system came to surpass its boundaries as a framework for technology scientists to also be adopted by politicians. In Miettinen's (2002) words, the concept “started to live a life of its own”, becoming an “instrument for governance”. This is likely to affect both the politics based on the the idea of NIS, and the contents of the notion, especially considering its much-contested fuzziness. Just like the idea of innovation as an evolutionary process, the concept of innovation system emerges from a dialectic relationship between research and practice. Technological change can thus be analysed through “the arguments used by different members of the relevant social groups in order to introduce new technology” (Johansson 1997, in Miettinen 2002).

The majority of the literature on innovation systems and particularly national innovation systems is developed by Western intellectuals studying innovation in advanced countries in the North. This is an admitted weakness of the concept for instance by Lundvall *et al* (2002), who at the same time note that the systems approach in principle is concomitant with development studies, because the affirmation that “institutions matter” generally has been seen as more relevant for poorer countries than for advanced market economies. If one is to translate the NIS to such new contexts, they argue, it is necessary to be aware of potentially adverse policy implications. Accordingly, a special focus must be directed at *learning* in the field of development strategies. These are aspects that must be considered when seeking to analyse a particular innovation system.

In addition, it can be valuable to combine elements from the different systemic approaches. The choice of theoretical framework should depend on the overall characteristics of each system, as this will give a more fruitful background for a comprehensive analysis that enhances our understanding of how the system works and how it can be managed. In the case of Argentina, a national approach serves as a tool for emphasising the role of national institutions (Lundvall *et al* 2002). Lundvall's (1992) view of the nation as a set of common cultural characteristics (and language) facilitating interaction and knowledge exchange should also be underlined, as well as previous political and economic events impacting on the current situation in the agricultural and R&D sectors.

4.3 Knowledge bases and technology flows

This section outlines the role of knowledge in technology and technology flow, and how innovation activities vary according to types (bases) of knowledge. A nuanced comprehension of knowledge flows and technology transfer is necessary when studying the relations between actors in innovation. Maliandi (2006) understands technology as a system composed of diverse techniques and a high degree of information and scientific methodology. Hence, technology flow must comprise more than the simple introduction of new products, and implies that the recipient also obtains knowledge about the technology in order to develop and improve technological capacity over time. The focus on knowledge in the notion of technology is crucial, and concomitant with the foundations of the IS approaches.

Knowledge and localised learning are core elements of innovation as an interactive process that takes place within specific social and institutional contexts. Many studies underline that the shift to a global knowledge or learning economy does not erode the importance of place; rather, it demonstrates the need for firms, regions and nations to keep pace with technological progress and avoid “lock-in” in order to stay competitive on the world market (Asheim *et al* 2006). In relation to this, Polanyi's notion of *tacit knowledge* is widely applied to point out that individuals, groups and places still matter in the context of globalisation of both production and innovation processes. Not disregarding this dynamics, Asheim seeks to “transcend the traditional codified-tacit dichotomy of knowledge” by pointing to how different industries draw on different knowledge bases in their innovation activities (Asheim 2007). The increasing complexity of such processes, particularly with respect to knowledge sources and actors involved, shows the need for scrutinising the knowledge concept, and three ideal types of knowledge bases are thus proposed. Knowledge bases have to do with the type of knowledge in itself, but also point to how this is integrated in organisations and techniques (Brink *et al* 2004, in Asheim *et al* 2007). First, the *analytical* knowledge base has its fundament in science, where R&D stemming from both companies and universities is crucial. This type of knowledge is to a high degree codified through documentation in reports, papers or patents. In comparison, the *synthetic* knowledge base spurs innovation mainly through the use of existing knowledge or by combining knowledge in new ways. Consequently, specific problem solving, testing and experimentation is more important than R&D, and make more use of the tacit dimension of knowledge. The third type of knowledge base is *symbolic*, first and foremost referring to cultural industries where sign-value and creativity are core components. Tacit knowledge linked to cultural specificities and *know-who* is, rather than university training and systematic research, the basis for product development and innovation (Asheim 2007; Asheim *et al* 2007).

4.3.1 Knowledge flows in biotechnology

Biotechnology's foundation on scientific knowledge makes it a typical example of technological innovation based on analytical knowledge. According to Asheim *et al* (2007) this implies that much R&D is undertaken by commercial firms in addition to research entities and universities. A main characteristic is close relations between industry and university departments as parts of networks. The importance of scientific research and methods such as laboratory investigations makes the production of new knowledge the foundation for innovation. This type of knowledge is to a large extent explicit, and is codified through description in reports and patents. However, more tacit dimensions also do play a role, particularly when emphasising early access to new knowledge. The authors argue that firms see it as crucial for their competitiveness to be ahead on accessing and absorbing new scientific knowledge before it is publicly available. This is linked to types of communication, where the general literature on innovation and communication is criticised for mixing *buzz* and *face-to-face* and their respective roles in different types of industries. The term *buzz* originates from what Storper and Venables (2002, in Bathelt *et al* 2004) explain as the special personal (face-to-face) communication and information exchange that take place between members of the same industry and cluster or location. *Buzz* entails unplanned and smooth communication in both professional and informal settings. Hence it is not a result of strategic efforts but is viewed as a natural by-product of the social relationships in a cluster – something from which the actors benefit by just “being there”. However, buzz must not be equated with face-to-face. This latter means of communication results from the physical co-presence of persons, where several types of communication can take place simultaneously. This facilitates exchange of complex and tacit knowledge and typically takes a more formal structure. In comparison, a main aspect of buzz is its non-deliberate character (Asheim *et al* 2007). A fundamentally new argument is that buzz does not necessarily require face-to-face contact but can also be transmitted electronically, potentially reaching worldwide.

The high reliance on codifiable knowledge in the biotechnology industry suggests that neither face-to-face nor buzz are of great importance. Notwithstanding that formal sources of information and knowledge are more significant, firms take use of other means of communication when seeking competitive advantages through accessing new knowledge before their rivals, as mentioned above. Face-to-face facilitates trust-building and exchange of ideas between researchers, whereas buzz transmits information on current research projects, scientific challenges and other unpublished details.

In a paper based on empirical evidence from the Canadian biotechnology industry, Gertler and Levitte (2005) study the geography of knowledge flows locally and globally. The particular knowledge intensity of biotechnology could in theory make it the most "footloose of all activities", nevertheless most literature and findings suggest that actors in the industry tend to cluster in spatially bounded areas, highlighting the interactive dimension of innovation. Agreeing with Bathelt *et al* (2004), the authors find that localised factors are important for firms' success, particularly in relation to financing, where locally based venture capital forms the core. However, buzz and localised learning are not sufficient in order for firms to stay competitive. Gertler and Levitte's study show that Canadian biotechnology companies involved in patenting are highly dependent upon global networks and knowledge flows, through exchange of IPR with foreign firms and recruitment of workers from abroad. This leads to the conclusion that openness and external orientation, in Bathelt *et al*'s words – *global pipelines* – is determinant for a firm's innovative capacity. But it is also pointed to other factors like particular location and development stage (age) of the industry. It is proposed that market size may matter, as limited available capital and experienced personnel locally encourage firms to seek external linkages. Furthermore, resource input from outside and new and bigger markets can be increasingly important for companies as they grow and expand. Here the Canadian study only mentions partnerships with American and European counterparts. This may be due to the relative concentration of advanced biotechnology activities in these countries, but as discussed earlier, common cultural facets and institutional contexts are prime if firms (and their clusters) are to benefit from interaction with external environments. If firms tend to focus on cooperation with partners from culturally similar and familiar countries, this may also be due to the fact that participation in global networks requires substantial efforts. Consequently a company must carefully select in which pipelines to invest to get the right combination of "similar and nonsimilar knowledge" (Bathelt *et al* 2004: 44).

The systemic nature of innovation highlights the importance of knowledge flows. However, knowledge does not flow freely and equally between participants in the system. Referring to Owen-Smith and Powell's (2002) thoughts on the importance of organisational form for knowledge flow, Coenen *et al* (2004) suggest that public entities are more active in exporting new knowledge than commercial organisations. Similarly, studying the emergence and sustainability of biotechnology clusters, Steven Casper[13] has found that the bulk of new biotechnology emerges from universities and reaches industry through spillover effects. Thus universities play a crucial role in the commercialisation of science, the core activity in a biotechnology cluster. The cluster concept is often associated with Michael Porter, who defines it as "a geographically proximate group of inter-connected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter 2000, in Bathelt *et al* 2004). Cluster approaches are also based on the systemic nature of innovation, underlining the importance of networks and social relations.

Coenen *et al* (2004) base their study of knowledge dynamics and proximity on the same concept of knowledge bases (*e.g*. Asheim 2007), and point to the importance of *epistemic communities* in analytical (scientific) knowledge. These communities, unlike communities of practice, typically comprise scientists and researchers seeking to enhance knowledge. This common objective encourages knowledge exchange between members of the scientific community irrespective of geographical location, devoting less attention to the application of the knowledge produced (Coenen *et al* 2004). Distinguishing in this sense between the motivations for knowledge production resembles the basic/applied research dichotomy. Basic research according to the Frascati-manual is research aiming at the "advancement of knowledge, without a specific practical application in view" (OECD 2002: 77). Conversely, applied research also seeks the advancement of knowledge, though explicitly intended as utilisation in practice. This clearly states that there are two basic categories of knowledge and knowledge production with different objectives. It is exactly the lack of hands-on implementation of basic research that makes Salomon (undated) stress the importance of the public support of basic research. First and foremost commercial agents see no motive for investing in the production of knowledge for no reason but the enhancement of knowledge. In addition, scientific research rests upon a constant renewal of the recruitment base – students which adopt and develop knowledge both within and outside academic institutions. However, the general dominance of private capital and corporate R&D in agricultural biotechnology (Cooke 2007) suggests that production and application of analytical knowledge are not separate domains. Rather, biotechnology illustrates the shifting role of science (as defined by Merton, see section 4.4.1), as firms' success depends on their ability to both produce leading edge knowledge and bring it to the market.

Recognising the workings of knowledge for innovation activities is thus critical for studies of biotechnology advancement in systems. However, knowledge does not always flow equally and freely within a system, and the continuous balancing between areas of concentration potentially leads innovation actors to stagnate. The next section reviews some key notions relevant for success and dynamism in national innovation systems.

[13] Lecture at the Norwegian Research Council, May 2008

4.3.2 Dynamism and efficiency in innovation systems

The structure of a system will inflict on the interaction that takes place between the participants (Fagerberg 2005). Typically certain types of communication and activities will be produced that lead the system in one direction or another. This refers particularly to the feedback functions that reinforce patterns of interaction within the system, locking the development path where actors may jointly enhance their competitiveness. Alternatively, a situation of lock-in can impede the system from absorbing external impulses that are crucial for securing continuous compatibility with broader societal structures and market changes. Whether an innovation system manages to adapt and redirect its activities, stagnates or even dissolves, will depend on its openness and ability to respond to signals from the environment. The importance of local buzz, face to face communication and global pipelines (see Bathelt *et al* 2004) becomes visible in this regard. Maskell and Malmberg (1999) introduce the notion of "un-learning" as crucial to avoid stagnation in a region or area, especially dissolution of institutions that impede future development. According to Niosi (2002) the literature on national innovation systems is in general overly optimistic. The prominent idea is that once the system is in place, innovation and learning will be enhanced. This can be linked to the rapid spread and popularity of the approach in academic as well as policy circles, which poses new challenges. With reference to Moscovici (1984), Miettinen (2002) argues that the transfer of NIS from science to policy and everyday discourse is characterised by *reification,* where "an abstract and tentative concept is made into a "given" self-evident and tangible entity". By introducing the concepts of *x-efficiency* and *x-effectiveness*, Niosi seeks to discuss the reasons for the unequal performance of different NIS. X-efficiency refers to the bounded rationality of actors, resulting in a situation where the output of an organisation or system is less than maximum, that is, the best performance observed in equivalent organisations. X-effectiveness on the other hand, has to do with how organisations and institutions comply with their missions. When comparing organisations or systems it is, however, important to distinguish between their differing objectives, as effectiveness measures the degree to which an actor reaches his individual goals. The author argues that situations of path-dependence and lock-in are the most common reasons for lacking efficiency and effectiveness in national innovation systems. Path-dependency shows that a system and its outcomes is contingent upon its historical background. This includes situations where some firms or actors have market dominance due to scale-economies and first-mover advantages, networks and standards excluding potential competitors, and technological lock-in stemming from past investments in tangible assets. This also covers investments in human capital, where learning trajectories within organisations may be difficult to change. For instance, Slater *et al* (2003) find that the relative focus in the biotech industry on herbicide resistance compared to other GM traits partly resulted from already available biological information and knowledge about building resistance in plants. Furthermore, reduction of uncertainty through contracts may also lead to less flexible and "frozen" organisations, and finally, Niosi (2002) uses the term *multiple equilibria* of economic systems to underline that what may have been optimal at one point is not necessarily equally efficient or effective at a later time. The locking-in of organisations in certain paths or characteristics can therefore lead to inefficiency or ineffectiveness.

Niosi's (2002) paper attempts to apply ideas and notions from economic traditions in the systems approaches to innovation, as a way of explaining why some national systems are less successful than others. However, the application of a more "economic" vocabulary constitutes a break with the foundation of NIS itself, and potentially compromises the dynamism of the approach. The development of the concept of innovation in systems was initially a reaction to classical and neoclassical economics' inability to include interactivity, learning and technological change in their rather static models of economic growth (Lundvall 1992). Niosi's focus on scale economies, externalities and sunk costs can therefore be misleading and divert attention from the dynamic and comprehensive elements of the NIS framework. Nevertheless, the paper makes a substantial contribution to a deepening of the concept by reviewing the impacts of lock-in and path-dependency, and by proposing concrete ways of assessing and comparing different national innovation systems in order to improve their performance. It also poses the core question of how the NIS concept is used in scientific and political circles, launching the debate of whether innovation systems *per se* are worth aspiring for.

4.4 Science, systems and diversity

Kaufmann and Tödtling (2001) have an interesting note on the difference between scientists and researchers working in different organisations. Their initial objective is to criticise the dominating understanding of innovation systems, as they argue that there is no single system fostering innovation. Instead, a conjunction of systems work together, each with their individual objectives and standards. The organisations and institutions that in the IS approach are treated as parts of one sole system are argued to represent several systems, innovation therefore being an outcome of such cross-systemic interaction. The main difference in how the systems work is linked to distribution and publishing of knowledge, and recompenses for the scientists' work. Whereas patents and commercialisation is the aim within companies and contract research, "pure" scientists are rewarded through publishing their research results. However, Kaufmann and Tödtling do not make an uncritical argument in favour of a substantially different science-paradigm ("entrepreneurial science") characterised by closer relations between science and industry. Rather they criticise this line of thought for mixing the notions of organisation with system, underlining that it is the university and the firm as *organisations* that are undergoing changes. The systems, however, remain intact in their “operating principles”. Their material suggests that firms rely increasingly on links with scientific environments rather than other firms as a strategy for pursuing advanced innovations. If we stick to the evidence concerning innovation based on scientific knowledge (*c.f.* Asheim's analytical knowledge base), the role of science-industry relations becomes even more obvious as firms involved in advanced innovation report universities and “pure” science to be a main stimulus. Such “pure” science, like basic research, refers to the enhancement of knowledge without commercialisation objectives, as mentioned above. Contrasting, although also a part of Kaufmann and Tödtling's (2001) science system, company and contract researchers are influenced by the workings of the business system and its focus on patents and commercial interests. The important factor in the interaction between the different systems is accordingly the *diversity*, because of the systems' differences in “modes of interpretation, decision rules, objectives and specific communication standards”. Their position is based upon an understanding of systems as self-referential and specific social entities. The concept of *organisation* is used synonymously with *institution*, as entities with formal rules and structures, requiring membership and performing specific tasks (Kaufmann and Tödtling 2001). An organisation, although being one bounded entity, can therefore participate in several systems at the same time. This is for instance the situation when a company conducts R&D, involving itself in both the science and the business systems.

This notion of systems and innovation implies not being able to think of innovation processes as a result of a “whole”. Instead the authors focus on the several systems involved, and the workings of boundary-crossing between these. This underscores the contingent aspect of innovation processes – it is not an automatic result of determined and coordinated work. The challenges for technology and innovation policies are obvious. If there is no single innovation system but rather a conjunction of systems with differing objectives, how does one refer to the co-workings of the interactions? And more so, how does one formulate policies to stimulate innovation? The authors are clear in underlining that fundamental mechanisms of the different systems must be respected. This means avoiding efforts to apply business logics to organisations within the science system, because it is the diversity between the systems that is most valuable in the interaction. Policymakers should instead create “bridging” instruments for communication and translation of rules in order to overcome obstacles that arise in the clash of systems (Kaufmann and Tödtling 2001). I argue that dividing the actors involved in innovation activities into different systems is problematic because it makes it difficult to study the structures of the interaction. The innovation systems approaches as outlined by Lundvall (1992), Nelson (1993) and Edquist (1997) focus on the generation of innovation through networks between a variety of actors *within* a system, facilitating an understanding of the relationships by considering them as part of a whole. Similarly, when studying regional innovation systems, Cooke (*et al* 1998, in Cooke 2007) divides the activities into two sub-systems of knowledge exploration (science) and knowledge exploitation (commercialisation), respectively. To the original outline can be added a “mediating” sub-system that “'translates', 'filters', and 'interpolates' implicit knowledge, assisting its appropriation as explicit or codified knowledge in the exploitation phase” (Cooke 2007: 28), not unlike the bridging instruments called for by Kaufmann and Tödtling. However, the NIS approaches assume that all participants strive for innovation on a more or less equal basis. Here, Kaufmann and Tödtling's (2001) article shifts attention to variations in the workings and objectives of actors and organisations (referred to as parts of different systems), clearing ground for a discussion of power relations between them. Incorporating the paper’s ideas of actors’ and organisations’ different objectives in the NIS framework can therefore be valuable. If distinguishing between organisations, institutions and systems, it may not be necessary to alter the original conception of innovation systems, as it is perfectly possible to acknowledge participants' different and even opposing aims and interests within the system.

4.4.1 Merton, Mode 2 and the Triple Helix

Biotechnology as a prototype of an analytical knowledge base (*c.f.* Asheim 2007) highlights the scientific grounds of the technology. At the same time, the distance between developments in science and the marketplace has been reduced, urging new debates and challenges. Increasingly fluent boundaries between disinterested knowledge enhancement and commercial interests in the biotech field actualise a rethinking of the science notion. How we regard the actors and processes of knowledge production is reflected in the way we deal with broader aspects of technology and innovation. Hence, our discussion should begin with a thorough look at the concept of science itself. The philosopher Karl Popper introduced “falsifiability” as the basic criterion for distinguishing science from non-science. For an idea to qualify as science, it must be clear enough to be potentially falsifiable. Similar essentialist ideals have also been put forward by Merton (1973, in Gieryn 1995). Also Cooke (2007) finds it important to revise the five Mertonian norms, presented with the capital letters CUDOS. The debate of IPR and biotechnology emphasizes the relevance of returning to conceptions of science. The CUDOS model is based on *communism* (or communalism) stating that scientists should desist from intellectual property and freely share their findings. Second, *universalism* requires impersonal evaluation of knowledge that is not based on gender, race, class or the likes. Thus it aspires to a meritocracy. Third, scientists should act and be rewarded according to *disinterested* motivations; and they must strive for novelty or *originality.* This point constitutes a modification of Merton's earliest norm set and accentuates the importance of freedom and independence in academic science. Ultimately, (*organised) scepticism* demands that all scientific claims be carefully tested and judged on strict criteria.

Merton does not use these ideals as boundaries for science. However, he does disqualify ideology, politics and “interested purposes” as non-scientific forms of knowledge production. The critics of these approaches are many, and particularly constructivists point to the fact that falsification in *practice* is a matter of socially negotiated interpretation. Merton's norm of universalism is hence also questioned, as norms are defined in everyday situations and according to actors and settings (Gieryn 1995). In place of seeking a universal definition, Thomas Kuhn (1962/1970, in Gieryn 1995) found a relativistic comprehension of science as going through paradigmatic shifts. A science paradigm is reached when there is consensus within a research community on what science is. But to what degree is there consensus? How does one establish agreement upon scientific principles, and who is included in the debate? These discursive matters are not brought up by Kuhn, but may be seen as relevant to analyses of science-industry networks and cooperation between different actors within an innovation system. As boundaries between science, technology, firms and society become increasingly blurred, the question emerges of when science or knowledge enhancement is for the common good, and when it serves private interests under other pretexts. This becomes particularly obvious when regarding biotechnology, where commercialisation of science and intellectual property rights are fundamental for innovation and development of new products. Knowledge and intellectual property can be seen as the main drivers of industrial development in the current world economy. The conversion of knowledge into capital is hence the new pillar of economic growth, fomenting close and interdependent relationships between science and industry (Etzkowitz & Webster 1995). Similarly, Etzkowitz (2003) argues that new relations between universities, government and industry (the Triple Helix, see below) impact upon the ideal of science itself, as capitalisation of knowledge makes the norm of disinterestedness invalid.

Nelson and Rosenberg (1993) discuss the close relationship between science and technology, showing that not only does new technology build upon new science but that it can also be the other way around. Furthermore, it is not always easy (or even sensible) to make a clear distinction between them. This may be particularly true for the field of biotechnology, where R&D activities are closely linked to the development and commercialisation of new products. According to the authors, this forms the background for the crucial role of both university and firm research within the innovation system. On the one hand emergence of new scientific knowledge may lead to new practical solutions, at the same time as technological development can spur knowledge enhancement and even new branches within science. Parallels to this debate can be found in the division between basic and applied research. The French technology philosopher Jean-Jacques Salomon also studies this changed relationship between science, technology and society. His argument is that the nature and the practice of scientific research has drastically changed, and that it now truly forms a network system of highly specialised groups in a mutual exchange relationship. This idea of networking as the new base for research and knowledge production is similar to the sociologists Gibbons' (*et al* 1994) concept of *Mode 2* – knowledge production as interdisciplinary, context-relative and problem-focused. This is opposed to *Mode 1* knowledge production which is academically based and discipline-centred. The ever closer link between universities and industries is hence the outcome of "the alliance between the cognitive and the institutional" (Salomon 2001, my translation). Many academics and others have looked to the novel structure of research and science environments, revolving around the interdisciplinary and network characteristics. *Science* can no longer be separated from *technology,* and these have again new ways of interacting with *society*. Scientific knowledge has its manifestations in society when it is applied as technology - utilisation for practical purposes. However, argues Salomon, the biotechnology field clearly demonstrates that research is no longer either fundamental or applied.

4.4.2 New conceptions of the university

Often there is a considerable time lag between the invention – the occurrence of an idea, and the innovation – its bringing out to practice (Fagerberg 2005). Salomon (2001) asks if Mode 2 is merely an attempt by industry to speed up this process, simultaneously responding to the conjunction between science and technology. However, not only is the industry finding more support in university research, the university is also becoming more and more dependent upon financial support from the industry. The independence of university research is consequently put into question (Salomon 2001). In the sense that private firms with commercial motives are selective in what kind of research they finance, it can be argued that this places direct or implicit constraints on the scientific knowledge produced. As illustrated by Cooke (2007) regarding the industry-academe life science collaboration in the Netherlands: "DSM[14] initiating *what* is to be researched and academe initiating *how* it is to be researched, a typical industry view of its status as financier of contract research".

As mentioned, Mode 2 illustrates the changed context for science. The idea is that scientific research is no longer autonomous, but determined by new links to industry and society. Based on a historical review, Etzkowitz and Leydesdorff (2000) criticise this stand and argue that Mode 1 – pure, independent science – is a mere construct of the 19th century institutionalisation of science. In fact, Mode 2 as knowledge production aiming at concrete problem solving predates Mode 1, because science has always been a means for dealing with practical challenges, for instance in navigation or mining. Instead, the authors suggest applying the model of a *Triple Helix,* which

[14] Dutch State Mining, having redirected focus from physics and chemistry to biology.

outlines the new relationships between university, industry and government, respectively. The Triple Helix redirects attention to universities as key players in innovation, contrasting the arguable focus on the firm in the national innovation systems approach. The thesis departs from an acknowledgement of societal transformations induced by new and knowledge-intensive technologies such as information and communication technologies (ICT) and biotechnology, where the university claims a more important role. Accordingly, new institutions and organisations arise from the overlaps between academia, state and industry, coined "tri-lateral networks and hybrid organisations" (Etzkowitz and Leydesdorff 2000). Seeing universities as the central for innovation is therefore argued to constitute a breach with the systems approach of Lundvall, Nelson and the like. Here, the university's main function for innovation has been indirect, as a support mechanism and a source of personnel and knowledge for industry. The private industry sector has within the NIS been the primary driving force for innovation activities, with complementary institutions seeking to facilitate its workings. A severe criticism is the lack of a power notion in the relations between the various constituents of the innovation system. The Triple Helix thesis may therefore be seen as a response to the altering of these power relations, as the university increasingly participates on the commercial arena. In fact, Etzkowitz (2003) holds that universities, industry and government interact as "relatively equal partners" in the Triple Helix model of innovation, contrary to earlier when private firms were seen as the prime motor of such activities. Similar to Kaufmann and Tödtling's (2001) idea of innovation as boundary-crossing between systems, the Triple Helix notion can make valuable contributions to the NIS framework. Rather than replace it, I will use Etzkowitz' insight to enhance the understanding of actors and power within the NIS.

Science-industry interaction is discussed applying several, also empirical, perspectives. In a paper based on a US survey of university researchers, Boardman (2007) considers the importance of affiliation with university biotechnology research centres for scientists' relations to industry. He makes a basic differentiation between research centres involved in biotechnology and those that are not, due to the particular knowledge intensity of the field. As a consequence, cooperation and partnerships between different types of actors and organisations are more important. This corresponds to the concept of knowledge bases (Asheim 2007; Asheim *et al* 2007), where biotechnology, drawing on analytical knowledge bases, features close links between science and industrial activities. Boardman distinguishes between university biotechnology centres linked to a National Science Foundation (NSF), i.e. with large budgets and several mechanisms for discrete technology transfer (IPR, spin-off firms) and smaller centres with few possibilities for transferring their R&D output. In terms of researchers' interaction with industry, the study shows that participation in NSF programs enhances such relations. This stands in contrast to other centres that do not benefit from large budgets or clear strategies for university-industry cooperation.

Furthermore, the analysis suggests that university scientists work with industry partners in a more informal manner than earlier thought. More important than discrete outputs like patent claims or establishment of new firms, biotech centres within large programs contribute to knowledge flows and less tangible outputs.

An important argument in this and other similar studies is the outstanding importance of universities in biotechnology networks and industrial development compared to other fields (Peters *et al* 1998, in Boardman 2007; Casper 2008). Boardman (2007) underlines that previous studies have tended to focus on universities' or university researchers' "discrete contributions" to the private sector, where companies networking with universities have higher growth and patenting rates or where new biotechnology firms spin off from universities or locate near them. However, as mentioned above, universities are thought to play a role in biotechnology progress also beyond direct firm support, through knowledge enhancement and the development of new techniques, and through providing a base of researchers and students that industry can draw on. Returning to Kaufmann and Tödtling's (2001) argument of systemic differences between commercial agents (industry) and "pure" science, universities clearly have objectives that do not necessarily relate to appropriating R&D results. Thus, the prime influence of science for innovation is through offering new information to the business sector or establishing partnerships for knowledge generation. The important point is in any case that collaboration across organisations with fundamentally different logics and objectives stimulates advanced innovations, and that the main value lies in maintaining the diversity within the network.

The innovation systems approaches have a clear point of departure in the focus on institutions, as innovation is seen as the product of relations and collaboration between a number of these. The concept of institution is nevertheless utilised in highly diverging ways, both explicitly and implicitly. Nelson and Nelson (2002) take a glance at how institutions should be understood in relation to innovation systems, because the "innovation systems idea is an institutional conception, par excellence". In an effort to match the two traditions of evolutionary and institutional economics, they argue that the former increasingly should incorporate *institutions* as a determining factor for technological advancement. Institutional economists, on the other hand, devote themselves to the study of institutions as frameworks for human action, but still lack a complete understanding of the role of technology. The objective of affiliating the two schools is based on a perception of institutions and technology as co-evolving and interdependent. A main point in the paper is to draw a distinction between physical and social technologies. A physical technology is, quoting the authors, "a recipe that is anonymous regarding any division of labor" (Nelson and Nelson 2002: 268). Social technologies correspondingly refer to the organisation and coordination of activities both within and across organisations, similar to common definitions of institutions as general habits of action and thought or "the rules of the game". Institutions, being social technologies, must hence be considered productive rather than constraining in the sense of effectively guiding human cooperation (Nelson and Nelson 2002). It is the linkages between technology and institutions (physical and social technologies) that are of particular interest to the innovation systems approaches. As physical technologies are considered the driving force behind economic growth, social technologies are of similar importance because they enable and facilitate effective use of these. These perspectives will be of interest when analysing the biotechnology sector in Argentina, as radical changes in the institutional set-up is argued to be crucial for the rapid spread of biotechnology in the country's agriculture.

Wagner (1998) outlines a number of aspects of the Mexican biotechnology industry that are of relevance also to the Argentine case. Although Mexico displays a significantly higher growth rate than Argentina, mainly due to NAFTA[15] membership and increased trade with the US, neither country has departed from the peripheral status and "unfulfilled potential" that characterises most of Latin America (Dicken 2007). A main argument in the paper is that the scientific community working with biotech is experiencing a shift in attitudes towards stronger interest in commercialisation and appropriation of the technology. Enhanced collaboration between scientists and business is articulated in a strategy for generating endogenous biotechnology and economic growth. Wagner sheds light on some of the challenges facing Mexico as an "emerging economy", where biotechnology has a potentially large impact on key sectors like agriculture, chemicals and food processing, to mention some. In Mexico, as in Argentina, R&D investments as of GDP are relatively small (0,35 % for both countries in 1993. [Science, vol. 267 February 1995, in Wagner 1998]). Weak scientific infrastructure is likely to adversely affect the interest of private industry in collaborating with universities and research institutes, further exacerbated by researchers' lack of market orientation. According to Wagner there is a significant gap between the research focus of Mexican scientists and the needs and objectives of commercial entities. This is first and foremost due to the widespread ideals of "pure" science that rather stimulate basic research and publishing, concomitant with Kaufmann and Tödtling's (2001) outline of the different (appropriation) logics of science and business. A characteristic of the Mexican biotech industry that is recognisable also in the Argentine context is the high dependence on imported technology (mainly from USA and Europe), that nevertheless is modified and adapted to local conditions. Wagner links this general lack of domestic technology to the weak science-industry relations. A weak legal framework in the areas of biosafety and IPR is also mentioned as a contributing factor to Mexico's poor technological level, as private firms are scared off from making R&D investments in the country.

The paper's main argument is that closer relationships between science and industry is

[15] North American Free Trade Agreement

necessary for the Mexican biotech sector to stay competitive on the international arena. Locally developed technology is also a better card for long-term development. The importance of such collaboration is likely to have increased over the last ten years as biotechnology has reinforced its position both as an advanced technology and as a driving force in agriculture. Wagner shows that commercially valuable biotechnology is depended upon close interaction between scientific expertise and market actors. A net importer of technology should therefore shift focus to encourage such strategic linkages in order to build independent innovative capacity. However, the challenges of too strong affiliation are not discussed, particularly the importance of diversity (between or within systems) for innovation (*c.f.* Kaufmann and Tödtling 2001). Similarly, power relations between the scientific community, transnational companies, local firms and other biotech actors are not considered.

4.5 National Innovation Systems and biotechnology

Modern biotechnology is characterised by a strong reliance upon scientific knowledge. Therefore, it is a technology based on analytical knowledge, as outlined by Asheim (2007; Asheim *et al* 2007). Such an analytical knowledge base builds on natural sciences and R&D activities, both within private companies, universities and research institutions. Because the knowledge to a large extent implies know-why (principles, laws), it is easily codified through reports, files and patents. This lesser reliance on tacit knowledge compared to other industries has consequences for the geography of biotechnology-related activities. As noted by Gertler and Levitte (2005), the particularly knowledge-intensive biotechnology industry tends to be highly concentrated in geographical areas. This stands in stark contrast to the idea of a knowledge economy where codified scientific knowledge flows rapidly and irrespective of local or national boundaries. This has provoked a massive line of literature to focus on the importance of clusters, agglomeration and different forms of spatial concentration in economic activities. Based on the notion of innovation as an interactive process, learning also increasingly takes place in the meeting of different individuals and actors. New terms have arisen to explain the dynamics of local versus global stimulus for innovation, focusing here on buzz and pipelines. Bathelt *et al* (2004) point to the fact that a combination of new knowledge from external sources and local, sticky types can be very valuable. The clue is, as discussed in Kaufmann and Tödtling's systems concept, the right mix of differentiation and similarity between participants and knowledge types in order for the interaction to produce innovative outcomes, as knowledge exchange and learning also can constitute a cost if the cultural distance is too big.

When the analytical knowledge base of biotechnology primarily draws on codified knowledge, global pipelines are thought to play a greater role. The tendency towards colocation and clustering of organisations within the sector must therefore reflect a parallel importance of tacit knowledge that is transferred in more and less formal manners through buzz and face-to-face communication (Asheim *et al* 2007). This should be seen in relation to the nature of knowledge creation and innovation in biotechnology, and the same authors underline that the active use of R&D results for the development of new biotechnology makes networks and university-industry relations especially important. Following this, universities often emerge as nodes around which enterprises choose to locate in order to access research results and qualified personnel. In addition, the spillover effect from universities leads to new firms basing themselves on knowledge produced in universities, as well as the creation of spin-off firms established by university researchers and students. Gertler and Levitte (2005) therefore find local knowledge flows and clustering to be of utmost importance for biotechnology companies. The role of the local competence base is further emphasized by locally derived venture capital as a main source of biotech financing. With reference to Cooke (2002), it is shown that the particular high risk and long-term aspects of investments in the sector require competent investors with knowledge about the researchers involved, obtained mainly through local contacts. According to Cooke (2006), venture capital is crucial because it helps firms to take better advantage of high R&D investments. Lengthy approval processes for new products in addition to high failure rates in product tests, add to the risky characteristics of biotechnology investments.

4.5.1 Pharmaceutical versus agricultural biotechnology

It is clear from the literature on biotechnology that pharmaceutical activities dominate over environmental, energy and agro-food biotechnology, both in terms of industry size and attention received. According to Cooke (2007), few regions meet the requirements for “significant agro-food bioregions”. An important factor distinguishing agro biotech from pharma is the relative dominance of large, multinational corporations like Monsanto, Pioneer, Dow and Bayer in agricultural biotech innovation. The author concludes with a set of two factors that compare agro-food bioregions to pharmaceutical, and two that distinguish the first from the latter. Common for both types of bioregions is the importance of universities as motors for research and new scientific knowledge. In addition, public research investments are significant, something that must be viewed in light of relatively small corporate R&D budgets, aside from some joint activities between a few large firms and universities, public research institutes and smaller dedicated biotechnology firms (DBFs). Conversely, agricultural biotechnology tends to be more reliant upon, as mentioned, dominant globally spanned corporations. Another aspect separating agro-biotech regions from pharma bioregions is the lesser R&D outsourcing to DBFs in the former. Rather, Cooke observes, in the

Dutch context this is done in-house by large food retailers, like Unilever and Nestlé. Financing structure is also seen to diverge between the two sectors, where private rather than public capital is more important in agro biotech (Cooke 2006). This is reflected in the relative dominance of corporate in-house R&D and research agreements between public and private institutions.

The growth of internal R&D within large, predominantly multinational, companies illustrates both the importance of scientific knowledge for competitiveness in the knowledge economy and the state of power relations that structures it. Cooke (2007) links this to the rise of universities as nodes of expertise in the biotechnology industry, threatening to outbalance private firms as the main drivers behind new technology. As a result, firms establish research departments (in Cooke's words “listening posts”) or acquire smaller firms in an attempt to gain direct access to prominent biotechnology clusters. The note suggests that proximity is of crucial importance, however in a less than geographical manner; what private enterprises seek is first-hand connections to new developments in the field. The author's focus is here on pharmaceutical biotechnology, arguing that universities and connected companies have reached a knowledge hegemony in the sector. The tendency towards firms relying on in-house R&D is certainly recognisable in agricultural biotechnology, as will be discussed below. In fact, the massive dominance of a few large companies in this area holding the main share of new product patents underlines the advantages of vertical integration along the value chain (Shiva 2000). Furthermore, there is no sharp distinction between agro and pharma biotechnology, as many firms and research centres participate in both domains. As noted by The Economist in 2000, agro-pharma linkages can spur synergies when it comes to basic research. However, the two sectors are widely differing in terms of market-related issues (Paul and Steinbrecher 2003).

In total the discussion about proximity in geographical and non-geographical sense highlights what literature on innovation and globalisation has found, namely that global flows of information and knowledge are crucial for locally based economic activities. Zeller (2004, in Cooke 2007) suggests that several forms of proximity is of importance for the innovativeness of biotechnology companies. These are, in addition to geographical, institutional, cultural, relational, technological, virtual, internal and external proximity. The role of *geography* is thus that it facilitates these other proximities (Cooke 2007). Studying biotechnology through a lens of national systems therefore means acknowledging the fact that innovation activities operate on a certain geographical scale and within bounded systems composed of a number of interrelated actors. Among the advantages of geographical proximity is the possibility for *channels* of knowledge, that unlike closed *pipelines* are more “leaky”, thereby enhancing local knowledge capabilities. Parallels may be drawn to Bathelt *et al*'s (2004) *buzz* notion. Second, “open science” policy from research centres induce spillover effects that nearby industry can draw upon. Hence researchers function as a link between science and emerging firms until the latter become “independent” through patenting and commercial activities. The combination of proximity and more formal convention is argued to be of advantage to both parties of science-industry interaction (Cooke 2007).

Concomitant with the arguments above this evidence states that university research and close relationships between private industry and publicly financed science is fundamental for the development of new agricultural biotechnology. However, whereas Cooke's pharmaceutical bioregions exert a high degree of outsourcing and partnerships with smaller firms and DBFs, a small number of multinational agro-chemical firms tend to dominate agro biotech. Accordingly, these bioregions also have a smaller number of firms. The nearly hegemonic structure of the agricultural biotech sector is the core of attention for as well political as academic circles, also spawning ideological and critical movements worldwide (*e.g.* Shiva 2000). Cooke's findings also finds resonance in Paul and Steinbrecher's (2003) critical book *Hungry Corporations: Transnational Biotech Companies Colonise the Food Chain*. Here it is pointed out that in 2000 nearly the entire market for genetically modified seeds was controlled by no more than five companies; Syngenta, AstraZeneca, Aventis, DuPont and Monsanto, respectively. Such horizontal and vertical integration within large corporations illustrates the altered geography of R&D industries, that have become more global as a result (Scoones 2002). This is also shown by the importance of global pipelines for clusters and innovation systems.

Biotechnology research is characterised by the need for high investments and large-scale financing, particularly due to costly laboratories, equipment and personnel. This situation is exacerbated by the long-term perspective of biotechnology, as developing new products is both time-consuming and risky. According to Paul and Steinbrecher (2003), this is an explaining factor behind corporate acquisitions of smaller, independent research entities particularly during the 1990's. In addition to mergers and acquisitions, granting IPR or licences of patented technologies to large companies is a way for universities and small biotech firms to secure financing of their R&D and hence survival. Compared to the pharmaceutical sector, agricultural biotechnology firms have generally displayed more difficulties raising investments for their projects. A feature of the agro biotech business is furthermore the close linkage between seed technology and chemicals (pesticides), as some of the biggest actors are market leaders in both sectors. Consequently, patented agro chemicals have spawned the development of “matching” seed, Monsanto's RoundUp pesticide and tolerant glyphosate GM seed being the most prominent case. This establishment of a *technology package* built around biotechnology has opened up for massive criticism of corporate oligarchic dominance that is argued to restrict production alternatives and cause farmer dependence upon their products. Firms are also accused of consciously limiting technology transfer in order to maintain and increase control over product sales (Paul and Steinbrecher 2003).

4.5.2 Intellectual Property Rights

As insinuated with the issue of technology packages, the concept of intellectual property rights (IPR) is important in many respects when studying biotechnology. Edquist and Johnson (1997) find IP laws to be one means by which uncertainty in innovation is reduced, through providing innovators prospects of appropriation. According to Maliandi (2006), biotechnology is a field where patents play a fundamental role in defining the relations of competition. Extending the view beyond the knowledge intensity of the technology, Paul and Steinbrecher (2003) find patents in the realm of biotechnology to be particularly controversial. First, it implies appropriation of other living organisms. Second, “new” varieties are generally outcomes of selective efforts of generations of farmers, whereas a patent is entitled only to one person or legal entity. Thus, the debate over IPR and biotechnology is potentially over whether biotech can be considered a technology like any other, or if its biological basis makes it distinct. The response from corporate circles is generally that adequate protection is crucial to promote investments and innovation, and hence economic growth. As earlier argued, studying biotechnology as an advanced technology but with distinct social implications is a fruitful approach.

The augmenting focus on the protection of research results and new products designates IPR as crucial for innovation activities. The concept of IPR refers in general to patents, petty patents, industrial designs, trademarks, know-how and trade secrets (Dodgson 2000). Whereas intellectual property traditionally has been managed on the national level, increased global integration and the establishment of international organisations for trade and economic activities is forging coordination of IPR systems across countries. The trend is towards stronger regimes and increased focus on legal rights connected to R&D results. Narula and Zanfei (2005) argue that MNCs are a driving force behind such standardisation processes through cross-national trade, investments and licensing activities. The relative dominance of a small number of large corporations in the development of new agricultural biotechnology strengthens the viewpoint of IPR as fundamental for biotech innovations, particularly because a global system for IP protection facilitates royalty claims and licensing fees for the same technology in several countries. Indeed, studies show that a strengthening of patent regimes spurs royalty payments to patent holding firms (Branstetter *et al* 2005). Prospects for obtaining patents can therefore function as an incentive for technology transfer to a country, and for agro conglomerates this can be of double value through both seed technology and chemical products. In this sense, IPR reforms may be positive for a country's technological level through encouraging technology transfer from patent-holding companies, especially in patent-intensive sectors. Also Yang and Maskus (2003) point out that stronger IPRs makes both innovation and licensing more attractive for developers of advanced technologies. Branstetter *et al*'s (2005) study further suggests that MNCs also conduct some R&D in the most advanced partner countries, whereas technology transfer to less developed countries focuses on absorption and modification of products. Considering that this to a large extent is accompanied by increased R&D spendings by the receiving partner, it supports the claim that stronger IPR regimes have positive implications for a country's research sector.

However, the fear of further sector concentration and corporate control is the background for the widespread scepticism towards stronger IPR, allegedly threatening biodiversity and increasing farmers' dependence upon input suppliers (Paul and Steinbrecher 2003). It is also claimed that increased importance of patents and IPR will inhibit open communication among researchers, because financing research projects to a large extent depends on possibilities for claiming new patents. This situation is contributing to many researchers joining large corporations rather than conducting their work in public or independent research centres, alternatively establishing research conventions with the private industry in order to access fincancing. The trend towards such science-industry interaction with commercial objectives is fundamentally contrasting to the earlier mentioned arguments of maintaining differences in objectives between commercial agents and “disinterested” knowledge producers. As argued by Cooke (2007: 16): “Scientists also learned the power of patenting”, taking that IPR should strengthen the scientific community's negotiation power towards the commercial industry and create new sources of income. Subsequently, closer relations between scientific environments and the biotechnology industry must also consider the increased focus on property claims on new inventions.

4.6 Biotechnology in society

Biotechnology, especially in the agricultural sector, is by far one of the most controversial technologies today, entailing both substantial capital investments and advanced knowledge. Its sophisticated features involve the design and production of living organisms with specific and desired traits (*c.f.* first and second generation GMOs). Civil society resistance against GMOs is particularly linked to ethical aspects (science “tangling” with nature), corporate control and potential environmental and health risks[16]. Nevertheless, the knowledge intensity of biotechnology makes it a leader in innovation, by Wagner (1998) described as the result of science “push” and market “pull”. Consumer scepticism naturally influences this market “pull”, placing public perception in a central role in biotech development. Tait and Chataway (2007) apply an interdisciplinary framework to study corporate logics behind GM innovations in Europe. They find that both internal firm strategies and exogenous factors such as government policies, regulations and public concerns affect the introduction of new biotechnology.

[16] Jan Husby, Norsk Institutt for Genøkologi (GenØk), Dagbladet 7 August 2007

The scientific fundament and analytical knowledge base in biotechnology has contributed to the overall focus on supply side mechanisms in the development of new technology (see for instance Cooke 2006). Science "push" may therefore be seen as relatively more important in biotechnology innovation. Furthermore, the mentioned market pull factor in biotechnology innovation is influenced (and limited) by the indirect relationship between GM innovators and consumers, in that seeds and pesticides first go through farmers and production processes (Tait and Chataway 2007). Roff (2008) discusses the effects of neoliberal deregulation of agro-biotech, arguing that preventing local bans on GM crops strengthens the industry and, referring to Harvey (2005, in Roff 2008) "exemplifies the harnessing of neoliberal ideology to corporate projects of capital accumulation". The author further argues that state preemption bills against municipal and county bans on GMOs, under the pretext of securing market freedom, limit political options and "vests power discursively in the hands of producers but practically in those of corporate elite". This review highlights the role of farmers in agricultural biotechnology issues. Their role as mediator between technology providers and consumers suggests that gaining their confidence is crucial for the success of new biotechnology, although, as asserted by Roff (2008), regulations impact on their choice. The hitherto dominance of "first generation" GM crops (input traits) further illustrates the relatively higher benefits for producers compared to the overall public (see section 3.2). Tait and Chataway (2007) outline this as one determining factor for the massive grassroots resistance in Europe, which again profoundly influenced regulations and policy making. Also, the adoption of the precautionary principle in the EU system was initially supported by the agro industry as an attempt to lower public disquiet. However, the principle seemed to be counterproductive in this sense, turning MNCs against the principle because it allegedly led to "decisionmaking based on pressure-group preferences rather than sound science" (2007: 32).

4.7 NIS as analytical framework

This chapter has provided a review of NIS as a framework for studying innovation. The concepts of *innovation* and *systems* have been scrutinised, highlighting on the one hand the evolutionary and complex features of innovation, while on the other hand acknowledging that such processes take place in the encounter of actors and interests in a systems setting. Thus, it is the quality and nature of the relations that determine the innovation outcome. Furthermore, the focus on the national level has been problematised in light of globalisation and regionalisation processes, concluding that many key actors nevertheless operate at the national level (Lundvall *et al* 2002; Dicken 2007). The fact that NIS approaches are rooted in the interplay between academia and policy circles (Miettinen 2002) also brings attention to the role of government and public institutions in innovation activities.

Maliandi's (2006) emphasis on the knowledge element in technology prompts consideration for how different types of knowledge are generated, conveyed and transformed into new technology. The notion of *knowledge bases* has thus emerged as crucial, denoting biotechnology as an archetypal example drawing on analytical and scientific knowledge (Asheim 2007; Asheim *et al* 2007). This has implications for the roles of the respective actors within the system, as well as for the communication between them. Science- and research organisations are accordingly perceived as vital, and knowledge is easily codified and transmitted through more formal channels. As a result, biotech firms take active use of both global links and local partners to absorb knowledge and innovation capacity. Following the discussion of science as constituent for biotechnology, the shifting position of scientific and research communities have been discussed using the frameworks of Mode 2 (Gibbons *et al* 1994) and the Triple Helix (Etzkowitz and Leydesdorff 2000). This has led to a redefinition of universities in innovation processes, achieving a pivotal role also in biotechnology (Cooke 2007). Placing biotechnology in the territory between science and commercial objectives also highlights the importance of IPR.

Chapter 5 presents the case of seed biotechnology innovation in Argentina. By employing concepts and insights from existing literature and prior studies, I will discuss the situation in the national system for agricultural biotechnology innovation. The empirical assessment departs from a visualisation of the actors involved and the relations between them, The figure presented below depicts the position of each institution within the Argentine NIS, and the relations are further structured around the vertical and horizontal dimensions. As will be argued, global-local (vertical) linkages constituted the main access point to GM technology during the first decade of agricultural biotechnology in Argentina. This complies with Cooke's (2006) synopsis of the industry as being dominated by large agro-multinationals. However, along with the enhanced technological base and R&D capacity of local firms, horizontal connections surge as strategic for building national innovation. As the model illustrates, private sector articulation organisations perform a key function in coordinating interests and promoting biotechnology. Furthermore, including farmers and producer organisations in the figure constitutes a breach with the general literature on the field, as studies on biotechnology and innovation tend to narrow focus to knowledge exploration (research organisations) and knowledge exploitation (commercial firms). However, I argue that the farmer community has been and continues to be crucial for the development and success of new seed biotechnology in Argentina.

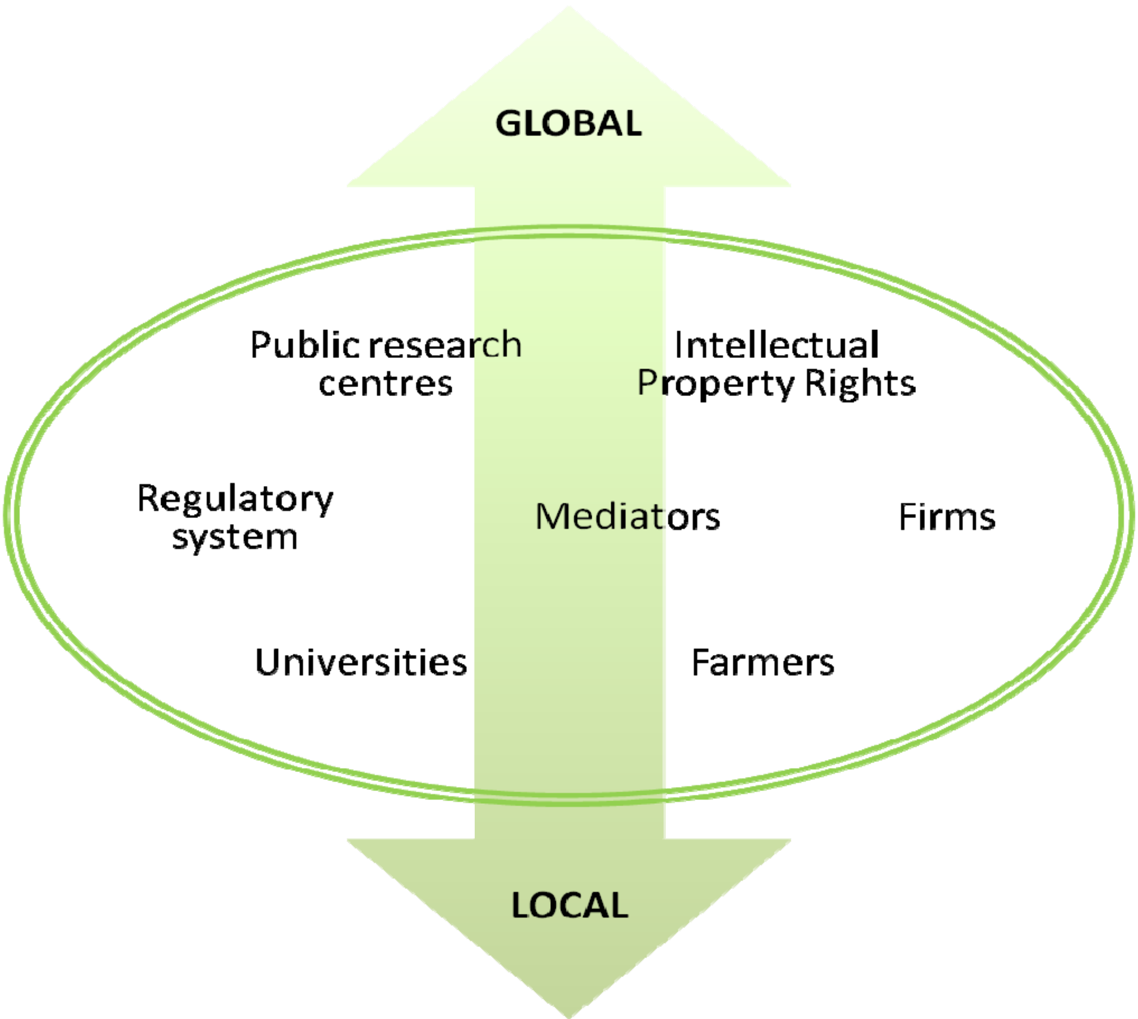

Figure 3: The Argentine national innovation system

5. STRUCTURING INNOVATION IN ARGENTINA

This chapter presents empirical data from Argentina analysed through the national innovation systems perspective. The material is based on interviews with researchers, industry- and government representatives, as well as public and private organisations working with biotech issues. In addition, I draw on several longer and more informal conversations with agents in the sector, as well as material from conferences, laboratory visits and a trip to a farm. The discussions in the chapter pivot around how the different actors work and interact, and how the nature of science-industry relations affects the production and use of agricultural biotechnology. The NIS approach provides a design for analysing the systemic set-up of actors and their relations as generators of innovation. The understanding of innovation as an evolutionary process forges interactive communication between R&D and knowledge production on the one hand, and application and commercialisation of this knowledge on the other. These have by Cooke (2002) been divided into two sub-systems within the wider innovation system. Asheim's (2007) concept of knowledge bases underlines this, where biotechnology draws on analytical knowledge derived mainly from the natural sciences. Advanced R&D milieus thus become of particular importance as firms and industry build their innovations directly on scientific knowledge. Conversely, the capital- and knowledge intensity of biotechnology makes prospects of commercialising discoveries crucial, driving corporations to involve more heavily in R&D activities. Recent scholarship further emphasises the importance of institutions for articulation between actors in the innovation system, by Amin and Cohendet (2005: 467) termed “'home base' institutions that act as a collective resource for both technological and non-technological innovation and learning”.

5.1 The arrival of biotechnology

The first biotechnology events were introduced in the Argentine agriculture in 1996. The first GM crop to be liberated was the glyphosate[17] resistant soybean, brought to the market by the nationally based agro company Nidera (Trigo and Cap 2006). The technology was, however, imported from abroad. The US corporation Monsanto managed to develop seeds with genes coding for glyphosate resistance, thereby facilitating effective application of their Roundup herbicide, as explained in chapter 3. An overview of the nine GM events approved for commercialisation in Argentina shows that these were launched by the following seven foreign-based firms in addition to Nidera; Ciba-Geigy, AgrEvo, Monsanto Argentina, Novartis Agrosem, Dow AgroSciences with Pioneer Argentina, and Syngenta Seeds (Trigo and Cap 2006). These are all global market leaders in their

[17] Molecule known for effectively exterminating a broad range of plants. Glyphosate was first commercialised by Monsanto as the herbicide Roundup, but the patent expired in 2000.

segments and many of them with close mutual linkages. Novartis was formed in 1996 when Swiss Ciba-Ceigy integrated with Sandoz[18.] One of the mentioned GM events was a multi-trait maize variety developed by Dow and Pioneer in conjunction. In 2006 Pioneer entered in a genetics licensing agreement with Syngenta[19], which again emerged from an agribusiness merger between Novartis and UK-based AstraZeneca[20]. As demonstrated, Argentina's biotechnology history started with approval of varieties developed abroad mainly by a handful of large corporations. The technological trajectory in the country therefore follows a global trend of agro-corporate oligopoly, as noted by Essex (2008). The general position of foreign companies in the Argentine biotech industry is further discussed below, especially in relation to the need for local business to collaborate with these. In the face of massive foreign influence in the biotech area, local actors do take on an increasingly significant role in technological development.

The next section reviews the role of institutional structure within the innovation system. As knowledge flows and technological development take place within and between organisations, a clear comprehension of institutional influence is necessary. Furthermore, as innovation is not confined merely to the technical level, the function of institutional change is relevant to take into account. This is the case more so when considering the particularly rapid incorporation of agricultural biotechnology in Argentina. Thus, the following sections discuss the impact of reforms of existing and establishment of new institutions working with biotechnology in the country.

5.2 Institutional change to promote biotechnology

As shown by Correa (1998), the Argentine national innovation system has long suffered from institutional confusion and inefficient government policies towards science and technology. Poor articulation within and between organisations concerned with scientific and technological activities impeded knowledge flows and thus innovative science, resulting in most R&D programmes confining themselves to modification of existing technology. However, the rapid developments in agricultural biotechnology during the last decade may be considered a breach with this situation, as several wide-ranging structural changes and shifts in policies continue to be made in order to facilitate the introduction, use and development of advanced biotechnology. Constructing a highly productive agricultural sector based on biotechnology requires smoother contact between scientific milieus and technology developers, private industry, authorities and farmers. This reflects the general literature on innovation in biotechnology suggesting that the high dependence on scientific knowledge produces closer science-industry relations (*e.g.* Asheim 2007; Cooke 2007).

[18] http://cibasc.com, http://www.novartis.com, 21 August 2008
[19] http://www.pioneer.com, 21 August 2008
[20] http://www.syngenta.com, 21 August 2008

Consequently, institutional reforms in the private as well as the public sector were initiated prior to the approval of the first GM crop in 1996.

Technological change and innovation takes place within broader contexts of norms and laws, institutions and organisations. New technology is dependent on this structural framework for its effective use and propagation. In an article reviewing the role of national innovation systems for economic growth, Freeman (2002) finds that intangible assets, by many classical economists denominated the "third factor", are the main explicans of economic growth: "The contribution of capital accumulation to growth depends not only on its quantity but on its *quality*" (Freeman 2002: 207), referring for instance to knowledge and skills as well as choices and foci of investments. Indeed, the core function of innovation systems is according to Freeman facilitating technical change through *institutional* change, forging that varying growth rates between countries depend on the (social) capacity for such changes. Lam (2005: 115) similarly postulates that *"organizational and technological innovations are intertwined"*. This literature treats the ability of an organisation to adopt new ideas and features as crucial for innovation. However, it is relevant to transfer some of these concepts to the systems level so as to consider the role of both institutional change and the creation of new organisations in the build-up of an innovative biotechnology sector.

Efforts to promote biotechnology in the public sector mainly refers to the establishment of a smooth regulatory framework integrating environmental, health and trade issues. Section 5.2.1 provides a more specific introduction to the system for approval and control of seed biotechnology in Argentina. In addition, the creation of new entities like the Biotechnology Office in 2004 within the Secretary of Agriculture both makes coordination of biotechnology activities more efficient and displays the overall priority of incorporating this technology in agricultural production. However, institutional changes and organisational innovation is by no means restricted to public offices. In fact, it is apparent that changes also in the private sector have been highly successful in synchronising initiatives and promoting biotechnology. Within the soybean sector where GM seeds now constitute nearly 100% of production, interest groups from R&D centres, input providers, producers, manufacturing- and commercialisation entities, and services are organised in a coordination institution for the soybean value chain. Uniting this broad set of sectors allows the association to work on a more long-term basis and view issues from several perspectives. Although each party is differently affected by a problem or a situation, an informant in the association for the soybean sector underlines that *"in the long run, being a chain, it's going to influence everyone in one way or another"*[21]. There is an equivalent non-profit association for the maize sector, the second most wide-ranging GM crop in the country. Five world-leading biotech multinationals in addition to the local company Nidera have also founded a separate information entity for the

[21] Executive value chain organisation, interview November 2007

promotion and development of biotechnology. In addition, most seed supply firms have joined the Argentine Association for Seed Suppliers (ASA), whose main task is promoting and representing the sector in official and political fora.

In total, these private sector organisations are examples of institutions that coordinate interests and efforts in the seed- and biotechnology industry. Through mutual memberships (most firms participate in several associations, and these are constituents of each other's organisations) and active interaction, private business constructs a network that ensures the strong position of the industry and facilitates knowledge and technology flows. Actors dealing with agriculture and biotechnology clearly emphasize coordination and information exchange in such formal settings, resonating Asheim *et al*'s (2007) notion of face-to-face communication (see section 4.3.1). In addition, dynamic relations are maintained in more informal meeting places such as seminars and conferences. As mentioned in the chapter on research strategy and fieldwork, several of my informants were well acquainted. Also, locating offices and activities within short distance of partners and collaborating organisations seems valuable. Of the seven firms and organisations I visited in the city of Rosario, six were located in the same building, also housing a wide range of associated actors and businesses. Revisiting the face-to-face/buzz discussion, it is likely that specific interest institutions together with shared facilities and geographic location enable trust-building and keep participants updated on ongoing projects and developments.

5.2.1 The regulatory framework – a brief overview

The issue of agricultural biotechnology touches on a number of socio-economic aspects which require fundamentally different approaches. The sometimes contradictory interests of economical and environmental concerns, for instance, make the management of biotechnology particularly difficult. Processes of innovation and flow of new technology take place within and are influenced by broader structures and institutional configurations, and a presentation of the main regulatory features in the Argentine context is hence in order. New events in agricultural biotechnology pass through three stages of approbation related to environment, nutrition and trade, supervised by the respective National Advisory Commission on Agricultural Biotechnology[22] (henceforth the Biotechnology Commission), the National Service for Health and Agronutritional Quality[23] (henceforth the Food Service) and the National Directory for Markets[24] (henceforth the Trade Directory). The Biotechnology Commission was established in 1991 under the Agricultural Secretary[25]. It is mainly an advisory organism for issues on biotechnology and biosafety,

22 CONABIA – Comisión Nacional Asesora de Biotechnología Agropecuaria
23 SENASA – Servicio Nacional de Sanidad y Calidad Agroalimentaria
24 DNM – Dirección Nacional de Mercados
25 SAGPyA – Secretaría de Agricultura, Ganaderia, Pesca y Alimentos

particularly concerning production and commercialisation of GMOs. The commission evaluates the release of GMOs in the ecosystem and assists in the development and administration of policies in this particular area. It is constituted of representatives from the public and private sectors working with agricultural biotechnology. Complementing the Biotechnology Commission, the main objective of the Food Service is to assess the nutritional safety of agricultural biotechnology (GMOs) according to current legislation and norms. The regulatory process and the roles of the primary institutions are illustrated in figure 4. All food and food ingredients containing GMOs are subject to safety evaluations in addition to laws concerning plant protection and registration. This will be further discussed below in relation to IPR issues. The first alimentary regulations were installed in 1998 and further updated in 2002 in compliance with international standards for risk analysis. According to MacKenzie (2000), nearly all regulations concentrate on products obtained through *genetic engineering* as opposed to *breeding* techniques, although the basis for monitoring are the perceived features and traits, rather than the process of modification. The third area of regulation undertaken by the Trade Directory considers the commercial consequences of GMOs on domestic and foregin markets. This line must be considered quite unique for Argentina compared to many other GM producing countries, and constitutes «one means by which non-scientific concerns may be addressed» (MacKenzie 2000). The primary tasks of the directory are assessing and influencing agricultural market tendencies, policy propositions and assisting domestic exporters with information and services.

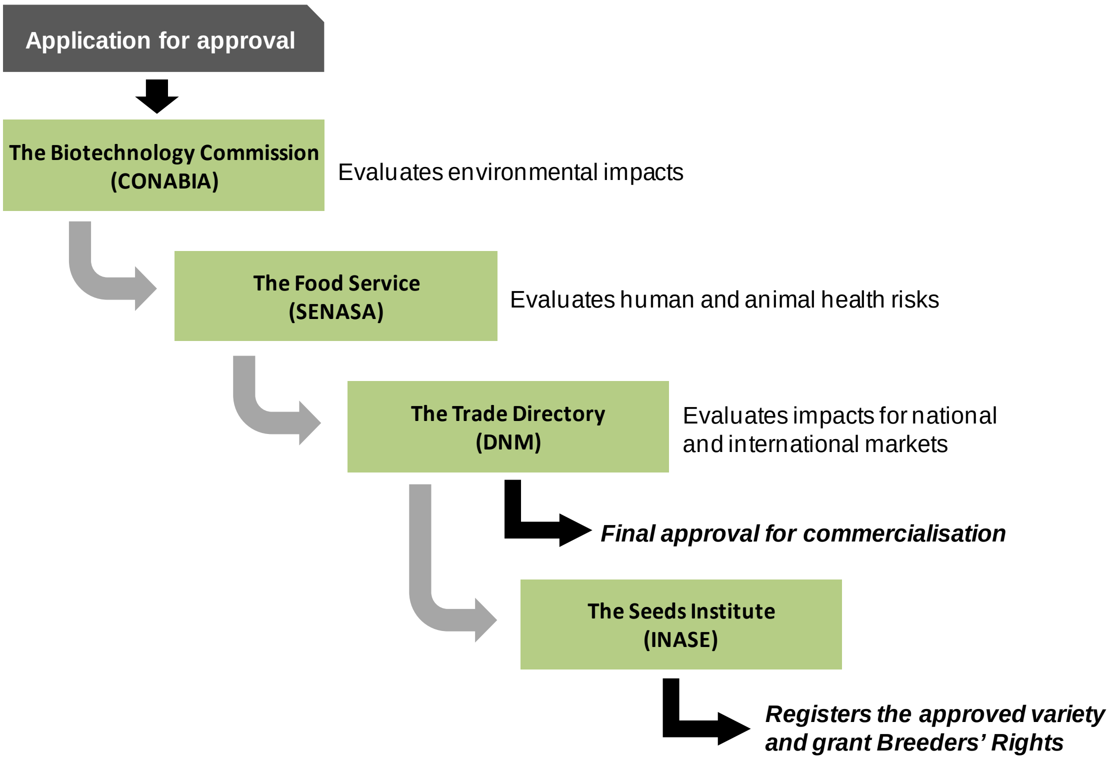

Figure 4: Approbation process for GMOs in Argentina

Source: Based on Roca 2003

5.2.2 “Safing” biotechnology

The regulatory framework is founded on a logic seeking to facilitate the introduction of biotechnology in the agricultural sector. Rather than perceiving the technology as an unsafe element, the administrative build-up advocates integrated efforts to smooth the regulation process. The approach followed by the majority of official authorities represents not only scientific (although contested) assurances of the safe use of agricultural biotech, but a broader discourse promoting biotechnology as instrumental for increased productivity and economic growth. To illustrate, agricultural biotechnology has by the Secretary of Agriculture been articulated as constituting a means for national development. Correspondingly, the «2005-2015 Strategic Plan for the Development of Agricultural Biotechnology» (Sagpya 2004) aims at converging all political and regulatory issues related to the issue. The plan has been developed against a backdrop of biotechnology playing an increasingly important role in the productive sector. The official website states:

> “Modern biotechnology is an integrated component of all agricultural production branches in Argentina. Its incorporation is accepted by our external clients, and its application contributes to environmental preservation. Finally, it has reached a high maturity level that provides increased productivity combined with technological self-sufficiency, and is available for any stakeholder that requires it.” [26]

Concordantly, the 2005-2015 plan (SAGPyA 2004) posits that increased productivity on the basis of GMOs, first and foremost RR soy bean and Bt maize, was key in mitigating the negative consequences of the 2001-2002 economic crisis. Strengthening the industry hence becomes crucial in maintaining and augmenting the country's competitive position on the world market. However, the plan recognises the challenges the sector faces in this context, as Argentina continues to be a net importer of biotechnology. Fear of being outplayed by other emerging economies like Brazil, India and China may in this sense induce more aggressive engagement in biotechnological innovation.

The institutional framework presented in the preceding section illustrates the attempt to facilitate a quick and open introduction of new biotechnology in the Argentine agriculture. Both the public and the private sectors have initiated reforms prior to and following the release of the first GM crops in 1996, either by establishing new organisations or by remodelling existing ones. In consequence, the country has been very effective in coordinating safety control, technology transfer, production and commercialisation. The policy of smoothing rather than inhibiting rapid introduction of the technology has consequently spread throughout the system, ensuring convergence between public as well as private interests. Despite widespread criticism against “bureaucratic” attitudes in many public offices, private business applauds the general positive stance in political circles

[26] http://www.sagpya.mecon.gov.ar/new/0-0/programas/biotecnologia/plan_estrategico_en.php, 21 September 2008

towards agricultural biotechnology. Two informants actually emphasized that acceptance of seed biotechnology never was a *political issue*, but first and foremost a result of the economic benefits for farmers and the country as a whole. One interviewee further outlined the regulatory framework as an "integrated analysis" where issues regarding consumption, commercialisation and exportation are treated simultaneously and in one block. The informant also presented the existence of the Trade Directory as somewhat special for Argentina, where market analyses allow the sector to adjust the production according to broader national and global tendencies. In fact, the regulatory system is referred to as a whole that since its inception in 1991 has effectively paved the way for the massive adoption of the technology:

> In 1991 they all sat down to figure out how to regulate this coming issue. And they approved it already in 1996 – it took five years to find out how to do it and how to evaluate it. This was very good because, like we say, it was a technology that came in through the big gate. That is, without anything to hide.[27]

An interviewee in the university system considers the regulatory system in Argentina to be based more or less on the same principles as in other countries. He argues, however, for a more liberal system especially in terms of environmental control: *"We are overregulating... There is no more debate – Greenpeace has left"*[28]. Nevertheless, he views the Trade Directory as a rather flexible organism contributing positively to the country's biotech sector. This is largely attributed to the overall conclusion that GM agriculture doesn't affect Argentina's position in the world trade negatively. As explained above, the directory is where issues outside the scientific realm may be considered (MacKenzie 2000). Public perception is central in assessing a product's market potential, implying that GM technology is viewed as safe and rather uncontroversial in Argentina as well as in the recipient countries. Indeed, a 2004 survey conducted by the Science and Technology Office[29] claims that the majority of the Argentine population accepts GM technology. The findings further suggest that the prime concern is access to sufficient and healthy food irrespective of the methods used to obtain it (SAGPyA 2004). Returning to the discussion around genetic engineering versus traditional breeding techniques (section 3.1.1), counter to the situation in Europe (see Tait and Chataway 2007) neither authorities nor the general public has taken a principal stand against biotechnology.

5.3 Intellectual Property Rights

Section 4.5.2 discussed the issue of IPR and its role for innovation. A main argument by scholars is

[27] Executive information office for biotechnology, interview November 2007
[28] Biotechnology professor, interview January 2008
[29] Secretaría de Ciencia y Tecnología

that patents in particular function as an incentive for innovation and technology transfer. Prospects for property rights and royalty incomes therefore make investments in research activities less risky for private actors. The high focus on IPR in seed biotechnology is associated with its position in-between science and markets, as property rights becomes the prime asset for technology developers. The following sections review the current situation in Argentina in terms of IPR and patents on plant biotechnology, revealing fundamental discrepancies from scholarship in the area as well as international standards.

5.3.1 Dismissing patents?

The rapid adoption of GM crops in Argentine agriculture suggests that the processes of technology transfer have been especially effective. According to Trigo & Cap (2006) the legal framework for plant variety protection (henceforth PVP, in place since the 1970s) created a favourable environment for GM technology. However, it is clear that intellectual property protection in Argentina is substantially weaker than in other countries where biotechnology plays a prominent role. Protection of biotechnology innovations is administered by the Seeds Institute, who grants rights and protection to plant breeders. Many point to the inherent discrepancies in the legal framework, making it difficult to interpret. Currently, the general law conserning IPR permits patenting. However, plants and animals are excluded from patents through a decree. Despite the fact that decrees are subordinated laws, the practice of breeders' rights are founded upon the exclusion of plants from patenting (UBA 1999).

All informants directly involved in biotechnology development, whether from the private or public sector, stressed the importance of a good framework for intellectual property protection. The general opinion of the current system is that it is weak and incomplete and that a strengthening is necessary for both technology transfer and domestic innovation. A biotechnologist working with IPR and patenting issues explains that the Argentine patenting law excludes all material that can be found in nature, disregarding of (genetic) modifications. This means that only certain DNA sequences or methods for plant variety creations can be patented. Protection of plant varieties are instead restricted to PVP. The problem is, according to the biotechnologist, that the system only allows you to protect determined varieties with very limited characteristics. Thus, a third person can easily build on your innovation (normally through crossing) and obtain protection for a very similar variety[30]. When IPR is considered both by scholars (*c.f.* Granstrand 2005) and my informants to be of increasing importance for innovation, this situation clearly poses challenges for agents involved in biotechnological innovations. As discussed earlier, strong legal frameworks probably make licensing profitable for foreign firms, thereby encouraging technology transfer (Yang and Maskus

[30] Patent adviser, interview January 2008

2003). This also applies to the quality of the technology, and one of my interviewees argues that due to a poor IPR regime, the country is missing out on the newest and most advanced technological developments. He states that a number of highly advanced technologies have emerged, but lacking prospects for protection of these innovations exclude Argentina from participating in the technological market[31]. Associating patents with technology transfer is done by Taylor (1994, in Maskus 1997), who demonstrates that foreign firms avoid licensing "best-practice technologies" if patents are not available. This is especially the case when there is competition from local innovators, making well-established patent practices necessary for the transfer of advanced technology. As shall be discussed, Argentina displays some signs of increased innovative capacity. However, one informant pointed to the risk of losing even domestic innovations. Although local actors put forward advanced technologies, insufficient patenting practices may cause innovators to rather commercialise abroad:

> It's not a technical question, they probably have interesting and commercially valuable developments. But maybe they're thinking more global. And well, maybe Argentina is missing out on this. We make developments in Argentina, but we're missing out on them. Because they can protect them other places, right?[32]

A common explanation for the rapid adoption of biotechnology in Argentina is the combination of lower costs and higher productivity offered by GMOs. In the case of herbicide-resistant soybean, the first GM crop to be approved in Argentina, the substantially lower costs of GM seed versus conventional was crucial for farmers' acceptance. Interestingly, Monsanto, who first developed glyphosate resistant crops, did not patent the gene coding for resistance. A number of similar varieties were in consequence soon produced, as only minor differences are required for another breeder to protect a variety. Paul and Steinbrecher (2003) state that Monsanto's patent application prior to the release had been rejected by the national patent office, because, as explained by an expert on biotech patents[33], plants cannot be patented in Argentina. However, why other forms of protection were not sought is unclear. The locally based company Nidera was as a result the first to commercialise glyphosate tolerant soy bean in 1996 (Trigo and Cap 2006). The logic behind Monsanto's approach can be understood in several ways. Lacking protection and the subsequent price fall on GM soybean seeds urged its rapid acceptance among Argentine farmers. The corresponding rise of glyphosate (Roundup) sales was also profitable for Monsanto, going from a global 28 million litres in 1997/98 to 58 million in 1998/99 (Paul and Steinbrecher 2003). According to a researcher in the field of agroeconomics[34], the GM soy experienced such a rapid

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[31] Economist, interview December 2007
[32] Patent adviser, interview January 2008
[33] Patent adviser, interview January 2008
[34] Economist, interview December 2007

adoption *"thanks to two major mistakes by Monsanto"*. First and foremost they failed to value the gene and patent it. Although Argentine law excludes plants from being patented, DNA constructions or specific methods for obtaining plants are not excluded. Furthermore, he stated, they ignored the fact that the patent on the complementary Roundup herbicide was soon to expire, thereby opening up for competition on the agrochemicals arena. This latter aspect is also underlined by Trigo and Cap (2006), showing a massive price reduction on gliphosate from around USD 10 per litre in the early 1990s to less than USD 3 in 2000.

The Monsanto case illustrates the impact of IPR regimes for technology transfer, where lean IPRs resulted in imitations and cheaply available technology. Whether this was intentional or due to failures by Monsanto, it is clear that the multinational fell short of much potential royalties or licensing fees as well as a top position in the soybean market. Particularly in light of the paradigmatic *knowledge economy,* where intellectual property gains priority over manufactured produce (Granstrand 2005). This trend is also observed by one of my informants:

> One of the major changes in the agricultural sector over the last years is the shifted focus from chemical input to biotechnology. Nowadays large American companies invoice far more from genetics than agrochemicals.[35]

Nidera is currently leader in the soybean segment supplying about 70% of seeds, whereas Monsanto has gained a stronger position in the maize market. Branstetter *et al*'s (2005) argument that strong IPRs incentivise technology transfer from MNCs therefore seems invalid when regarding the seed technology, although the Roundup herbicide may have been the company's main focus. Rather, domestic imitators and the entire Argentine agro as a technology importer were the main beneficiaries of the lacking protection of the glyphosate resistant soybean. Maskus (1997) shows that emerging economies have an interest in limited protection in the early stages of development, facilitating import and imitation of technology. However, when moving up the "technology ladder" these countries should strengthen IPRs in order to attract more advanced technology and stimulate local innovation. As illustrated by the statement above, rapid adoption of an unprotected technology served as a port of entry to GM biotechnology for Argentina. Higher calls for an improved legal framework also by local agents is likely to reflect the need for protecting enhanced innovative capacity within the country. According to a newly established biotech firm, the IPR issue in Argentina is an area that needs to be improved. A main problem is, however, the lack of qualified personnel in the patenting office[36]. Referring to the same company, the IPR adviser quoted above is sceptical of the potentials for rewarding their innovations with the current legal framework: *"My impression is that they're very innovative. (...) But personally I don't see how they're going to*

[35] Economist, interview December 2007
[36] Executive biotechnology firm, interview November 2007

protect their innovation."[37]

5.3.2 Extended royalties

In general the literature on innovation and IPR asserts that patents and other forms of protection is crucial for making investments and technology developments attractive and profitable for private actors. The choice to adopt PVP and limited patenting as the main mechanisms for IPR in Argentina is therefore perceived as a threat to future innovation efforts in the sector. This is primarily related to the prospects for royalty payments which, as claimed by one firm representative, provides the chief bulk of funding for genetics- and breeding programmes: *"The firms provide varieties and genetics appropriate for each producer, which in turn must make his contribution to maintain the system"*[38]. A primary concern is hence the prevalence of illegal *brown bag*[39] sales, which is estimated to constitute as much as 80-85% of total seed sales in Argentina[40]. The situation is exacerbated by the limited success in defeating the practice, by another firm executive explained as bad habits and the free-rider problem:

> Obviously the producer doesn't want to pay [for the technology]. He wants to enjoy it. It's like with music downloaded from the internet – does the author have the right to claim money or not? Here it's quite similar. So, some Latin-American countries accept that they have to pay – Brazil, Paraguay, Uruguay. But not Argentina. So today the newest biotechnology advances arrive much slower than in those countries.[41]

In order to deal with the problem of defective royalty payments, a group of large biotech companies has launched the term "extended royalties". This refers to the commitment of the farmer to pay annual royalties for the continuous use of seeds that fall under the system. According to my informant in Nidera, this is the *"only way to sustain the R&D programmes of each firm"*[42]. In cooperation with Monsanto, Pioneer, Don Mario and several other market leaders, the company is running awareness campaigns to establish this custom. However, faulty mechanisms for control along with the prevalence of brown bag sales severely undermines the system. Despite general acknowledgement of the need for protecting new biotech inventions, the issue of extended royalties is by no means uncontroversial. Several producer representatives have fought the initiative, which is seen to go against the fundamental right of each farmer to set aside seeds for resowing[43]. Extended

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37 Patent advisor, interview January 2008
38 Coordinator Nidera, interview December 2007
39 Brown bag (in Spanish *bolsa blanca* – white bag) refers to the illegal sale of seeds without state control. This generally occurs when the farmer saves more than the authorised quantity of seeds for his own use, thus avoiding royalty payments when selling the product.
40 http://www.cyta.com.ar/ta0603/v6n3a3.htm, 11 October 2008
41 Executive input firm, interview November 2007
42 Coordinator Nidera, interview December 2007
43 This right is actively advocated by the Agrarian Federation of Argentina (FAA), which largely consists of small- and medium scale rural farmers.

royalties is a clear attempt by technology developers to place the issue of IPR on the agenda, highlighting that royalty payments are crucial for private investments in biotechnology. Thus it manifests the increasing importance of protecting innovation, particularly as national actors move from adaptation and modification of foreign technology towards more locally based and endogenous innovation. However, due to the many contested aspects that arise, the industry may find it difficult to legitimise the demand.

5.3.3 International harmonisation

Argentina has been since 1994 a member of the International Union for the Protection of New Varieties of Plants (UPOV), established in 1961 as an expression of international agreement on the need to protect the right of plant breeders. To date there are 64 members of the organisation (June 2007). The UPOV convention is specifically designed to encourage the development of new plant varieties through a "*sui generis* form of intellectual property protection"[44], and has been revised on several occasions in order to adjust to new technological developments. UPOV articulates the following requirements for a variety to qualify for protection:

> "(i) distinct from existing, commonly known varieties, (ii) sufficiently uniform, (iii) stable and new in the sense that they must not have been commercialized prior to certain dates established by reference to the date of the application for protection."
>
> UPOV (2008)

The most important functions of UPOV are harmonisation and cooperation between member countries, and assisting with the implementation of the UPOV system of plant variety protection. The Argentine system for plant variety protection is administered by the Seeds Institute and functions mainly through the use of two separate though complementary registers. First, the *national register for cultivars* allows for the commercialisation of a plant variety. However, inscription in the register does not grant any form of property right. Instead, the above mentioned breeders' rights are admitted through the *national property register* for a period of 20 years. My informant in the institute therefore underlines that inscription in both registers is necessary for someone to both protect and commercialise a new variety[45].

According to a 2005 UPOV report on the impacts of the system, the creation of the Seeds Institute in 1991 led to a considerable rise in titles for protection granted to resident breeders in Argentina. Similarly, harmonisation with the UPOV convention three years later spurred an increase in applications by foreign breeders, reaching an approximately 50/50% distribution of titles between residents and non-residents. 70 titles were accordingly granted to Argentine residents between 1992

[44] http://www.upov.int/index_en.html, 31 July 2008
[45] Coordinator INASE, interview January 2008

and 2001 (versus 26 during the previous ten-year period). For non-residents the equivalent numbers were 62 titles granted from 1994 to 2003, against 17 during the ten years prior to the UPOV harmonisation (UPOV 2005). Although the strengthening of the legal framework for property protection proved beneficial for both domestic and international agents, the UPOV harmonisation process clearly improved foreign breeders' possibilities for obtaining protection titles, increasing their share of total titles granted in the country. This is resonant with the viewpoint of MNCs promoting international standardisation of IPR protection, because it facilitates trade, investments and licensing across national borders (Narula and Zanfei 2005). In much of the literature discussing the role of IPR for innovation and technological level, it is argued that strong legal frameworks induce both technology transfer and endogenous innovation. However, recent scholarship also suggests that due to the high technological skills and capital intensity of biotechnology, only a limited number of the most advanced countries are able to participate in the biotechnology race (Varela and Bisang 2006). Rather, the core of power is shifted to a limited number of large corporations who obtain increased control of patents in biotechnology through a trend of mergers and acquisitions of smaller firms.

The general call for improved property protection by informants foremost in the private sector shows that patents are judged to be stimulating for biotechnology innovations. One of my informants further opined, contrary to the above-mentioned fear of corporate patent oligopoly, that IPR is more important for small firms[46]. Because R&D occupies a relatively larger part of budgets in small compared to large firms, protecting their technology and claiming royalty payments also becomes more important. Although international IP standards facilitate transfer and licensing of technology by large multinational corporations, this may also be of value for smaller and less experienced actors. As later examples will confirm, locally based innovators also work towards obtaining patents on their technology abroad. Thus, harmonisation of patent regimes is likely to profit nationally based emerging innovators. Indeed, two specialists on biotechnology IP were clear on that Argentina would benefit from consenting to international IP standards, specifically the Patent Cooperation Treaty (PCP): *"The local applicant interested in protecting his innovation in many countries would obviously benefit a lot if Argentina were part of the (PCT) project"*[47]. Considering the trend of increasing local innovations, the informants further regard it to be merely a question of time before Argentina signs the treaty, being after all *"a political matter"*.

5.3.4 Vested trust in industry

As argued above by Pengue (2001), there is a critical lack of independent research on real and

[46] Coordinator INASE, interview January 2008
[47] Patent advisor, interview January 2008

potential adverse effects of agricultural biotechnology in Argentina. In a 2007 newspaper article, Husby argues that this is in fact common worldwide. Poor grants to these lines of investigations, problematic conditions for researchers who publish "unwanted" results and reluctance from the biotech industry to provide test material are presented as main reasons for the actual situation. In consequence, assessments of environmental and health risks are done only on the basis of what the private companies themselves present[48]. Indeed, the Argentine system for examination of new varieties displays the fundamental flaw described by Husby. My informant in the Seeds Institute explains the methodological approach taken by the administration towards control of new plant varieties before issuing property rights:

> At the international level there are three systems[49]. One is the official system where it would be like we took care of all the field trials ourselves to verify the requirements for protection, novelty and distinction of the variety, homogeneity and stability. In your country you surely apply this system. But this requires a series of costs and human resources, as well as personnel, infrastructure, depots and sowing of the test cases every year. So there is another system also recognized at the international level, which is validation of results done by other agents, among them the breeders themselves. This is the system we apply. Accordingly, in the application [for property rights] the breeder presents the results of these exams.[50]

The informant claims to see no inconvenience with this system, because the Seeds Institute has the right to access the tests carried out by the applicant. Furthermore; *"when we have doubts, we too can conduct tests"*. Constituting a ground pillar in the regulatory system for biotechnology, the unquestioned use by the institute of data and results provided by the industry reflects a situation of trust and cooperation between the public and the private spheres. The position gained by industry also suggests that lacking resources in the public sector press on solutions where private actors to some extent control themselves. This relates both to insufficient funds devoted to external or government led scrutiny, as well as limited access to qualified personnel. As stated above, Argentina is short on breeders, engineers and is criticised for a poor legal framework for agro-biotechnology.

By establishing relationships based on cooperation and mutual trust with authorities and government agencies, the interests of biotech firms and promoters have found both acceptance and support in the regulatory system. The economic success of GM crops and the lack of concrete evidence of their potential malfeasance has further evaded the basis for criticism.

48 Jan Husby, Norsk Institutt for Genøkologi (GenØk), Dagbladet 7 August 2007

49 The third type is presented as a "mixed system" where the applicants' tests are complemented by official exams the subsequent year.

50 Coordinator INASE, interview January 2008

5.4 Public efforts for research and development

Development of GM biotechnology is in many senses associated with broader changes in the agricultural sector. Figure 5 shows the gradual increase in annual yields of soybeans and maize in Argentina. However, improved productivity cannot only be attributed to the arrival of biotechnology, as new technologies also in other areas contribute. Indeed, Katz and Bercovich (1993) show that productivity in the Argentine grain sector more than doubled between 1960 and 1980. They link this first and foremost to the diffusion of machinery and organisational technologies, and the following spread of chemicals and new crops (soybean, sorghum, maize hybrids). According to the authors, public sector agencies were heavily involved in these developments, particularly the National Institute for Agricultural Technology (INTA. Henceforth *the Agricultural Institute*) and the Council for Science and Technology (CONICET. Henceforth *the Technology Council*). However, the private industry in agricultural machinery, agro-chemicals and hybrids is noted to take on leading roles in these segments, especially through the involvement of multinationals and their local subsidiaries. This trend is likely to have been strengthened in recent years with the adoption of biotechnology in the agricultural sector, as illustrated with the few but large corporate actors in GM technology above. The Agricultural Institute was established in 1956 after a long period of decay in the agricultural sector, and contributed especially during the first decades to improvements in and diffusion of new agricultural practices and hybrids. Several successful R&D projects have aided the spread of both production techniques and genetic material, primarily through the many decentralised experimental fields and branches. Nevertheless, the institute is considered to fall behind on international advanced innovations in the biotech sphere (Katz and Bercovich 1993). Regardless of potentially lower technological standards, the Agricultural Institute is currently a national leader in terms of property obtentions on new varieties. Numbers from the Seeds Institute show that property titles are distributed roughly 50-50 between national and foreign agents. Of appropriated investigations with domestic origin, around half was undertaken by the Agricultural Institute[51].

[51] Coordinator INASE, interview January 2008

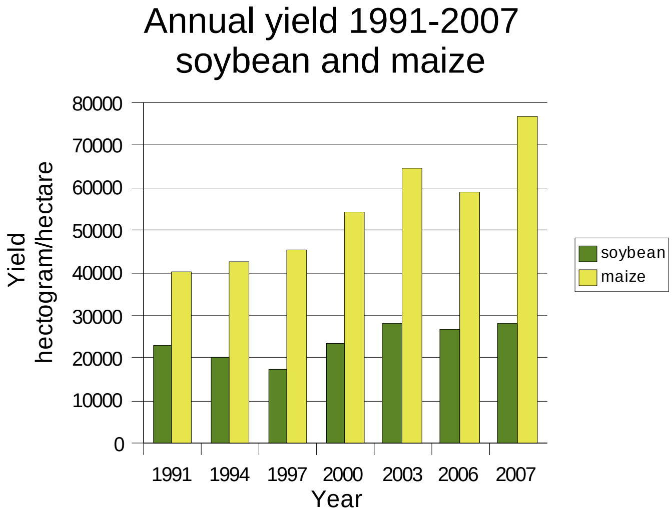

Figure 5: Annual crop yield Argentina

Source: FAO statistics (Faostat) 2008

The Technology Council came into being in 1958, two years after the establishment of the Agricultural Institute. The council focuses on four main scientific areas related to agriculture and engineering, biology and health, natural sciences and humanities and social sciences[52]. They are heavily involved in both R&D and technology transfer in the biotech sector. According to Katz and Bercovich (1993), the council experienced a drastic expansion in staff and tasks during the 1980's, resulting in "bureaucratic disorder" and inconsistent quality of research. The entity now counts over 5000 researchers, of which just under 800 work in the line of agricultural sciences and engineering. The Technology Council further administrates a number of R&D agreements with the public and private sectors, many through the Office for Technology Transfer created in 1985[53]. In relation to biotechnology, the most noteworthy is perhaps the joint endeavour with the two private firms Bioceres and Biosidus to establish the Institute of Agrobiotechnology in Rosario (INDEAR. Henceforth *the Biotechnology Institute*), which will be further presented below. The council has also launched a support programme for techno-scientific development with the market-oriented science company DuPont, where the latter provides a sum of USD 25.000 to the "execution of the best research project" in biotechnology[54]. An interviewee directly involved in the Technology Council's biotech work explains that the council possesses a range of instruments for technology transfer, where a human resources exchange programme with the private sector is particularly relevant. The project "Researchers in Firms" allows professionals from the Technology Council to spend up to four years in an external company, which then pays 50% of the salary. Private industry can thus

52 http://www.conicet.gov.ar/INSTITUCIONAL/Descripcion/objetivos.php, 26 August 2008
53 http://www.conicet.goc.ar/VINCULACION/principal.php, 27 August 2008
54 http://www.conicet.gov.ar/NOTICIAS/portal/noticia.php?n=2874&t=6, 26 August 2008

draw on the council's extensive bank of information and take use of well-informed investigators[55].

According to Katz and Bercovich (1993), small and medium size enterprises are the main beneficiaries of agreements and research cooperation with CONICET, as these lack R&D infrastructure and financial sources. As we have seen, the particularly high investments in knowledge and equipment within the biotechnology sector exacerbate the entry barriers for small and newly established firms. The industry is by consequence dominated by large multinationals (Paul and Steinbrecher 2003; Cooke 2006). This underlines the need for public sector involvement in order to build up a diversified range of market-oriented firms. Several of the interviewees pointed to the practical shortfall of public R&D, accusing these environments of producing too basic and irrelevant knowledge. In fact, one of the biotech firms I spoke to emerged from an attempt to bridge the gap between science on the one hand and commercial production on the other. In an interview, the company director explained that Argentina was internationally renowned for their good technological level, but that the general objective of the Argentine researcher was to "*publish papers in prominent journals and well, it basically ended there*"[56]. The company therefore seeks to overcome these discrepancies by identifying needs and challenges in the sector, and find solutions to these problems.

5.5 The university sector excluded

The function of universities in technological development and innovation has been widely discussed since the launch of the IS approaches. Standpoints range from viewing them as fulfilling a minor role as a provider of new students to constituting a main locus for knowledge production around which firms cluster. The concepts of Mode 2 (Gibbons *et al* 1994) and Triple Helix (Etzkowitz 2003) seek to revisit the role universities play in innovation. How these institutions interact with other innovation actors and society as a whole is at the core. This section discusses the situation for Argentine universities in light of the mentioned problematic, also revealing domestic challenges that are somewhat atypical in the global context.

The overall impression of the university sector as producer of high quality but commercially irrelevant knowledge is widespread among my informants. From the business sector, five interviewees underlined the problem of too little and commercially worthless university research. Another six informants from private sector associations and public offices reported to have linkages with universities. These were, however, exclusively of technical or educational character, as biotechnology R&D within university institutions generally is found to be insignificant. A common

[55] Biotechnology professor, interview January 2008
[56] Executive biotechnology firm, interview November 2007

view is that the leading universities enjoy a skilled workforce and supply the sector with well-trained personnel in the form of students. Nevertheless, they are thought to maintain a too traditional focus in biotechnology activities, causing public sector research to miss out on innovation opportunities that could also be of interest for private firms. Katz and Bercovich (1993) place the weak position of Argentine universities in the context of political priorities. Arguably, governments particularly during the military rule systematically sought to undermine the already neglected university institutions, resulting in these “just marginally contributing to the national system of innovation” (Katz and Bercovich 1993: 466). Focusing R&D efforts in alternative institutes like the Technology Council and the Agricultural Institute to the detriment of universities is correspondingly considered a concious strategy that has been followed over years, allowing broader political objectives and a stronger military sector to be attained. This has undoubtedly affected the structure of the research and educational sector, and compromised public science and technology efforts. Indeed, five informants placed explicit emphasis on the limited or lacking government investments in R&D activities. Although two also praised the cautious trend of increased state fomenting in research, long-time neglect of the area is described as a major reason for Argentina's technological lag. The executive of a small seed and chemicals firm explained that years of poor investments in education and research have led to the current situation where university faculties only engage in very basic and far from outstanding biotechnology research:

> If Argentina doesn't put heavy resources in public research, the situation will become even worse. The road is *knowledge*. (...) The thing is that public research has to be the driver.[57]

The interviewee doesn't see the situation changing at the moment. As a prior member of the Commission for Science and Technology, his experience with public research groups was one of competition and lacking coordination resulting in wasted resources:

> Maybe the resources were present, but four groups were investigating the same thing. And these four weren't always coordinating their work nor exchanging information, because they often compete. So it's a quite serious issue. When these groups later interacted with industry because they had progression, the people either shifted to the private sector or they left the country. After which they had to form a new team.

The impression of public institutions as poorly coordinated is reflected also in Correa's (1998) review of the Argentine NIS. Here he argues that policies in general have been unable to acknowledge the differing dynamics of science and technology. Furthermore, “the evident lack of articulation among different actors” (1998: 722) hampered potential technological developments and domestic leading-edge science. The reported failure of university groups to dovetail their respective R&D efforts is a manifestation of internal circumstances in combination with broader

[57] Executive input firm, interview November 2007

structures restricting the sector's ability to perform attractive research. Limited resources seem to contribute to rivalry between groups and individuals, that instead of interchanging information and knowledge follows mutually disadvantageous strategies of secrecy. According to Coenen *et al* (2004), production of analytical knowledge like biotechnology happens in epistemic communities consisting mainly of researchers and scientists. The primary function of such communities is enhancement of a particular knowledge area, with limited interest in the application side of the knowledge. In Amin and Cohendet's (2005: 469) words, people can be linked through knowledge associations regardless of geographical location because “'being there' defined as relational or social proximity is possible without physical proximity.” Thus, the connectedness brought on by membership in the same scientific community should stimulate cooperation and knowledge production for its own sake. This brings us to the debate around the differing objectives and means for appropriation in “pure” science versus commercial R&D milieus, as described by Kaufmann and Tödtling (2001). I have earlier argued for incorporating the aspect of *diversity* between actors when dealing with innovation, although ignoring the subdivision into a science and a business system proposed by the authors. This relates to the differing logics of various forms of knowledge production, as shown by Salomon (2001) when he argues that it is essential to also endow research “outside the market” that doesn't yield short-term profits.

It is on these bases he criticises the Argentine science structure where public R&D has been disengaged from education and confined to institutes like the the Technology Council and the Agricultural Institute[58]. This is a contradictory situation to Mowery and Sampat's (2005) assertion that engaging in both education and research activities simultaneously can be more valuable for an institution than narrowing down to one of the two. This facilitates interactive relationships between the university sector and industry, forging both the spread of scientific research and the integration of wider socio-economic and business needs in public R&D efforts. Clearly, Coenen's “epistemic community” has in the Argentine context not been allowed to prosper due to maladministration of the university sector. Coupling teaching and research has been discouraged, depriving students of updated professors and downplaying the importance of universities as founts of scientific knowledge. The structural politics that has confined public universities to a minor player in research activities simultaneously threatens the fundamental knowledge base in Argentina. For instance, my informant in the university system argues for the establishment of a multidisciplinary institute for biotechnology within the UBA[59], which will strengthen the university's position and the national biotech system as a whole. In order to participate in the technology race in agro biotech it is necessary to interlace knowledge and competencies across disciplines. However, internal discussion

[58] Clarín (Argentine newspaper), interview with J. J. Salomon. 2 February 2008
[59] University of Buenos Aires

as well as insufficient technological capacity create obstacles for both university-based research programmes and integrated education in the field of biotechnology. The interviewee states that Argentina suffers from a general deficit of human capacity, especially in the form of breeders and engineers, as well as a weak legal framework – basically *"everything that is needed to generate biotechnology"* [60].

As such, administrative difficulties and inefficiency are seen as major inhibiting factors for university R&D. When possible, professors and researchers therefore seek alternative channels for administering their work, such as the the Technology Council. In this way cooperation and linkages with other entities function as a pathway to the marketplace and more advanced developments, reducing the importance of the university. Katz and Bercovich (1993) posit that as few as one in four Argentine university professors engage in research activities. As suggested by my informant, the few that do are discouraged to coalesce research and teaching efforts. Consequently, the university sector is disarticulated from broader innovation networks. It further proves inapt to function as the prime generator of scientific knowledge and capable workforce that the literature on innovation generally calls for.

5.5.1 New strategies for university research?

Reducing university efforts in R&D activities implies excluding these institutions from the technological drive. In addition, it counteracts any integrated approach to innovation and impedes the establishment of a network for biotechnology in the country. The result is a fragmented system for science and technology unable to produce innovation, as upheld by Correa (1998). He further finds that universities are even more negligible in biotechnology compared to other fields, meaning that private firms see little gain in using the university sector as a knowledge and technology partner. Instead, "linkages with the productive sector have been weak, and basically consist of services such as technical assistance, training and consultancy" (1998: 749). My empirical material reflects this position, and several informants from the private sector report weak relationships with universities. The following illustrates:

> The universities in Argentina perform very little research. It's very basic, and very little. In general what they do is more technical assistance, for instance: adaptation of different products according to furrow distance, fertilizer density, appropriate seed times. But when it comes to themes of biotechnology, it's very little. It's due to many years of lacking investments in education and research. It's a serious issue in Argentina. With the INTA we do some things, but not with the universities, they do little research.[61]

It is clear then that the Argentine universities traditionally have played a minor role in innovation

[60] Biotechnology professor, interview January 2008
[61] Executive input firm, interview November 2007

and production activities, particularly in the biotech sector. Decades of poor financing and undermining of R&D activities have reduced these institutions to a support structure for business rather than a leading edge technology provider. New scholarship on the area demonstrates that private firms in the pharmaceutical industry tend to locate around and draw on outstanding universities (knowledge spillover), whereas agro-biotech finds itself dominated by a few big transnationals (Cooke 2006). As a consequence, universities may find it important to cooperate with the private sector as large firms are clear leaders in agricultural biotech R&D. Mowery and Sampat (2005) note that a trend of reduced government funding and higher competition for R&D resources causes universities to alter their behaviour in the search for financial sources. This refers particularly to "entrepreneurial" activities and linkages with industry that help the university sector move beyond "knowledge for its own sake" (2005: 210) and participate directly in innovation processes.

On the one hand, this could provide an opportunity for Argentine universities to enter the technology race and participate in the national innovation system. Indeed, the financial aspect is key for Argentine institutions collaborating with business. According to a university professor in biotechnology, the university regards programmes for technology transfer to external actors as a complimentary source of income. By exporting knowledge and technological developments to private firms, public R&D teams can contribute to overall economic growth and simultaneously secure financial resources for their own activities. However, close interaction with business potentially constitutes a two-edged sword in that private commercial interests determine research priorities and eventually the technological trajectory. It is likely that the weak structure of public institutes and universities make them more susceptible to external influences. Biotechnology's position between science and the marketplace further exacerbates the propensity to let economic prospects steer R&D priorities. One of the few critical voices in the field is preoccupied by the unconcerned networking between university professionals and commercial actors: *"Through this contact universities and professors are consciously and unconsciously transmitting attitudes pro biotech"*[62], underlining that the big issue is lack of critical perspectives on agricultural biotechnology in the country.

As stated by Coenen *et al* (2004), public R&D entities are more proactive in passing on new technology than the business sector. This assumes that universities engage in R&D solely for the sake of knowledge enhancement, hence adopting an "open science" policy. However, as suggested by Mowery and Sampat (see above), financial aspects are increasingly influencing activities in the university sector. The reported consideration of technology transfer as a financial source for the UBA (and other universities) is a clear illustration of this.

[62] Environmental researcher, interview October 2007

Although the university sector is perceived as playing a key role in long-term biotechnology developments, lacking resources, bureaucratic mess and a fundamentally “wrong” attitude towards utility and commercialisation are seen as obstacles for prosperous university R&D. Rather, the educational institutions confine themselves to more technical assistance and basic science:

> The [university] groups generally have an interest more in basic science, although there are exceptions. For instance, some had success in obtaining new varieties through crossing. But using traditional techniques, you know, not modern technology.[63]

Later in the interview, the same informant commented positively on the emerging tendency toward larger public investments in the scientific area. The problem thus far has been lacking resources, limiting university research to basic and unimportant fields. He argues, however, that with sufficient investments and knowledge capabilities, this can form a starting point for more commercially relevant R&D:

> ...obviously one thing leads to another, right? When there is critical mass, you can expect firms to appear. (....) The laboratory groups in the universities and the Technology Council are generally strong in basic science. It's like they say, this generates a critical mass of people so that you also have people with interest in more applied science.

The quotations simultaneously illustrate the somehow ambiguous attitudes within the biotech industry toward the real and ideal functions of the university. The question of which tasks the university sector should perform enters the core of the science-industry debate. Like Salomon (undated) argues, basic science (knowledge enhancement without commercial objectives) is dependent upon public funding in order to stay clear of business influences. Whereas public universities commonly is the major channel for government investments in science and education, the locus of effort in the Argentine context has to a large degree been redirected from the university arena to other public research organisations, mainly the the Technology Council and the Agricultural Institute. The statement also emphasises what the literature states, namely that scientific knowledge constitutes the backbone of biotechnology (*i.e.* the analytical knowledge base outlined by Asheim 2007).

The NIS approach highlights the importance of interaction, meaning that innovation performance is contingent upon the quality of the relationships between relevant actors. As noted by Correa (1998), this has been an evident issue in the Argentine context because national policies have dealt with science and technology in a too narrow way. Real *innovation* suffered due to exaggerated focus on science compared to the technology side, and inadequate coordination between sectors and institutions. Consequently, the system took shape as one of *science and technology* rather than *innovation,* the former applying a more linear notion of technical change.

[63] Patent adviser, interview January 2008

Like elaborated in chapter 4, NIS builds on an evolutionary understanding of knowledge and innovation, where interactive relationships and continuous feed-back loops among actors and sectors drive the science and technology processes forward. Unlike stances viewing science as a building block for technology, the IS approach interlaces the two as simultaneously drawing on and developing the other (see Nelson and Rosenberg 1993; Edquist 1997). Returning to Correa (1998), Argentina has traditionally built policies in this area on “outdated” and incomplete perspectives on scientific and technical development. However, the biotechnology field demonstrates that newer conceptions among innovation actors tend to perceive technological development as the outcome of integration and cooperation among various public and private actors. The case of the Rosario Biotechnology Institute (INDEAR) presented below exemplifies how science-industry articulation is fomented by innovation actors. Indeed, the knowledge intensity of biotechnology underlines the importance of cross-sectoral communication and knowledge flows. Bringing forth new innovations requires a reorganisation of the system, having implications on power relations and the technological trajectory. Thus, we may consider the heavy focus on agro-biotech in Argentina over the last decade to constitute a shift in the general attitudes towards science and technology, where attempts to build a proper innovation system in biotechnology produce changes in science-industry relations.

Building up institutions for knowledge production that also manage to communicate with the productive sector therefore seems crucial from a theoretical as well as an empirical viewpoint. However, the Argentine case suggests that the inability of the university system to perform advanced research has prompted alternative solutions to develop the country's biotech sector. In light of what Salomon (2001) coins the privatisation and commercialisation of research, interactive partnerships with private industry are increasingly celebrated as a new knowledge paradigm. He therefore stresses the importance of state funded basic research, being “outside the market” and therefore best situated within the university realm. This being absent, universities may become subject to both internal and external pressure to establish linkages with commercial actors, as university professionals in the country seek alternative channels for conducting their work. It is likely that decades of politically motivated downplay of the Argentine universities have exacerbated an already difficult situation, compelling researchers to enter the business arena in the quest for R&D funding. Also, external pressure arises when networking and inter-sectoral cooperation becomes a political priority nationally as well as globally.

Following the discussion over public research and the university system, the role of private sector initiatives in biotechnology is now considered. How firms access and develop knowledge is analysed in light of recent scholarship on the area, leading to a discussion about enhanced capacity building and local innovation in Argentina. To illustrate the role of public-private cooperation in biotechnology, the case of the biotechnology research institute INDEAR is presented. Prior to this, focus is kept on domestic industry's linkages with foreign actors and the dynamics of adaptation and modification of imported technology.

5.6 Collaborating with the multinationals

Private business in the Argentine biotechnology sector generally seeks to establish good relations with foreign firms and multinationals. This can be understood both considering local firms' limited ability to compete with stronger and more advanced companies, as well as the overall importance of participating in wide-spanning networks. Asheim and Isaksen (2000) discuss the dynamics between regionalisation and globalisation, showing with reference to Amin and Thrift (1992) that a locale (a cluster) may constitute a node in a global web. Drawing on international connections in combination with local resources therefore becomes a potency for firm dynamism. Such vertical integration in the value chain can take several forms. The term *buzz* has been discussed earlier, by Asheim *et al* (2007) characterised by non-deliberate and informal communication that takes place in both intra and extra local settings. Accessing global channels can in this sense provide small, emerging firms with valuable information about ongoing projects and general R&D trajectories. Similarly, Bathelt *et al* (2004) have shown that global pipelines are crucial for a company to stay innovative. Participation in networks beyond the local and national level enhances the firm's knowledge base and, as stated earlier, provides a source of diversity which prevents path dependence and technological lock-in (see Maskell and Malmberg 1999). Bathelt *et al* argue in addition that prospects for accessing new markets may stimulate global linkages. Indeed, the director of a local biotech firm explains that external markets are part of their business strategy:

> The idea is to constitute one of many suppliers in the seed market. In Argentina to begin with, but it could also be in other markets around the world. We already have close linkages to Uruguay and Paraguay, and we're establishing a link with Brazil. [64]

The director also highlights the importance of collaborating with large foreign firms, something they consider a way to go international themselves. The relations are arguably very good, because *"we consider ourselves not as competitors, but as potential allies, because with a multinational you can't compete. For costs, scale, experience..."*. This stand is copied by a young but emerging input provider. The firm is currently not involved in direct R&D activities but licenses technology from leading, primarily multinational companies such as Monsanto. Although they consider themselves innovators and aspire to provide the newest and best technology, they find that this was best done through partnerships with carefully selected technology developers. As the executive explains: *"Us*

[64] Executive biotechnology firm, interview November 2007

against enterprises with millions of dollars in research, we can't catch the train, we don't have the ability"[65].

Biotechnology firms in Argentina experience large difficulties in competing with large-scale and well established companies particularly with regard to R&D. Returning to Cooke (2007), innovation in agro-biotechnology (as opposed to pharmaceuticals) is to a large extent dominated by large chemical or food corporations. This is largely due to the potential of linking seed and agro-chemicals on the one hand, and vertical integration along the food chain on the other (Paul and Steinbrecher 2003; Dicken 2007). Also, the particularly high knowledge intensity and the need for high, long-term R&D investments impose barriers to entry for small-scale actors, leaving large multinationals in dominant positions (Gertler and Levitte 2005). Nevertheless, among the most prominent actors in the Argentine biotech sector is the national company Nidera, which, despite historical linkages to a Dutch trading firm, mainly focuses on the local market. This company will be presented in a separate section below.

With the exception of Nidera, most local firms in the biotech sector acknowledge their limited capacity to compete with big multinationals on the R&D arena. This situation reflects the literature on agricultural biotechnology stating that major innovations are done by a few, global corporations with internal, resourceful R&D departments (*e.g.* Cooke 2007). In addition, these MNCs seek to access new developments in the field mainly through mergers and acquisitions. Varela and Bisang (2006) show that this has been the case also for Argentina, where the economy during the 1990s became dominated by a handful of globally reaching enterprises. Their substantial upper hand in biotech R&D arguably caused local agriculture to depend on and simply adapt imported technology. An interesting note in this context is a fresh rumour about a possible acquisition of one of Argentina's fastest growing seed firms by Monsanto. The firm already enjoys close relationships with the multinational, and the idea is arguably to maintain its independent function. Monsanto's motive is on the other hand to access the wide distribution network of the local business partner[66]. As will be shown later on, the seed industry is dependent upon close relationships with farmers. Local salesmen and distributors function as one possible channel through which new agro biotech can circulate, thus being of great value to technology developers.

The disability of local industry to confront foreign R&D intensive entities was also acknowledged by one informant, stressing the USA as the core of advanced agro biotech. Argentina's potential accordingly lies in importing and adapting technology. "*There simply aren't enough investments available"*, he said, considering that one single NorthAmerican university often

[65] Executive input supply firm, interview November 2007
[66] www.lanacion.com.ar/nota.asp?nota_id=1064624, 30 October 2008

disposes larger budgets for this type of research than the whole of Argentina[67]. Similarly, my informant in a licensee firm posits that *"in Argentina it is almost impossible to achieve individual, transgenic events. (...) It has to be a mega-firm, or a dedicated R&D firm, like you see in the USA."*[68]. Developments based on already existing genetic material is however far easier, but also he emphasises the problem of intellectual property and lacking accreditation of research. Having completed more than a decade of agricultural biotechnology in Argentina, GM events of foreign provenance are still more common. This is why firm-firm and national-global collaboration remains important in order for local industry to avoid being outcompeted by large multinationals. However, the next section will also point to the role of such alliances to enhance local capabilities and build innovation.

5.6.1 Global stimulus for local activity

As criticised by Kaufmann and Tödtling (2001), general scholarship on innovation systems tends to assume that science-industry interaction generates innovation. The authors add to this that mechanisms are needed that "translate" differences in logics in order to smooth communication and collaboration, and that "standard" institutions for technology transfer are inadequate in this context. Indeed, section 5.2 shows that the biotech industry in Argentina greatly benefits from the presence of mediation entities that focus specifically on promoting their interests. As a complement to knowledge and stimulus from external sources, integration of local actors plays a key role in strengthening national innovation. By fomenting local contact the system's participants seek to optimize efforts and balance interests, thus securing the *efficiency* and *effectiveness* called for by Niosi (2002). To demonstrate, an interviewee in the soybean association acknowledges the role foreign firms and investments play in the development of biotechnology in Argentina, but highlights the importance of local capacities:

> ...the [technological] progress goes beyond the foreign companies. I think companies and research from abroad surely have more ambitious objectives, maybe they have novelties that we don't. I don't know to what extent. I think research is so well developed in Argentina (...) They're creating a lot of conditions locally, it seems to me that much is produced locally, that there are much intellectual resources.[69]

The analytical knowledge base of biotech and its high reliance on codified knowledge makes global linkages particularly relevant, as exchange of IPRs and personnel is increasingly done across country borders (Gertler and Levitte 2005). The discussion above illustrates how firms in the Argentine biotech sector emphasise collaborative links and partnerships with foreign business,

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[67] Economist, interview December 2007
[68] Executive input firm, interview November 2007
[69] Executive value chain organisation, interview November 2007

mainly because direct *competition* is not an alternative. Framed in the NIS approach, cooperation between local business and corporations based abroad is an outcome of mutual knowledge exchange and learning (Lundvall 1992). Furthermore, establishing good relations to global actors may be a way for local firms to receive external input; it becomes their "pipeline" that secures technological renewal and dynamism (see Bathelt *et al* 2004). Both public and private actors in Argentina see the value of international networks and there is general awareness of the "globality" of biotechnology. For a Rosario-based licensee, building "strategic alliances" (referring primarily to Monsanto) is a strategy for obtaining a leading market position[70]. Again, the impossibility of competing with multinational capital intensive enterprises makes collaboration a favourable alternative, also associating the firm with renowned products and companies. As discussed in relation to Nidera's shift from adaptor to innovator, licensing can be a starting point from which to build independent R&D capacity. My informant indeed states that they desist from advancement research, instead focusing on modifying already tested technology to local conditions. The firm nevertheless recently obtained permission to conduct such trial processes, implying that *"we could do tests with a new transgenic event, which we are not at this point. Instead the events enter our testing network at a later stage"*[71]. Despite not planning to enter the R&D segment in the near future, they are managing to incorporate new knowledge and capacities into their range of activities. It is the product of new know-how combined with existing skills, as praised by Bathelt *et al* (2004) arguing that integrating locally based and external knowledge can spur new value for individual and groups of firms. Thus, taking a collaborative approach towards other market participants not only reflects the firm's inability to compete, but also builds pipelines through which new knowledge can be accessed.

Not unlike the previous example, the executive of another young biotech company declares that they aspire to be *"a nexus to abroad"* and a mediator of new technology to be tried out in Argentina[72]. Establishing links with the exterior provides the firm with technology and novelties to combine with their existing skills. Of primary importance in this sense is solid knowledge about and experience with local conditions. This is indeed a crucial concept in biotechnology because

> You don't bring in the American germ plasm as it is. You cross it with the Argentine germ plasm to adapt it to temperature, drought, water, local environmental conditions, or resistance towards local diseases.[73]

Adaptation and modification is, as underlined earlier, fundamental in the country's biotech sector and illustrates the importance hitherto of imported technology. But it also highlights the technical

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70 Executive input firm, interview November 2007
71 Executive input firm, interview November 2007
72 Executive biotechnology firm, interview November 2007
73 Executive input firm, interview November 2007

and applicable aspects that require extensive place-bound knowledge and hands-on testing. This elucidates why adaptation of biotechnology, in deriving from combined existing and new knowledge, can constitute the outset for more innovative efforts.

The literature on innovation in systems tends to emphasise the need for nodes to participate in tactic pipelines in order to enhance already existing local assets. Bathelt *et al* (2004) advice policy makers to prioritise pipeline stimulus rather than building local buzz, because buzz "largely takes care of itself". However, the Argentine case suggests that local biotech actors actively sustain mutual linkages to enhance their technological capacity. Despite the wide recognition of connections to foreign places and international environments, investments in local partnerships seem of primary importance for my informants. This is resonant with the more recent idea that local assets are indispensable for international competitiveness (Porter 1998, in Asheim and Isaksen 2000). The concept of innovation systems is inherently based on the local (or non-global) as shaper of innovation. Hence agents in innovation should focus on mutual cooperation and reinforcement. Biotechnology innovation thus features a dialectic relationship between the local and the global, taking that "firms must be both open to new knowledge (embodied and otherwise) from a wide range of sources and reliant on local relationships for capital and know-how." (Gertler and Levitte 2005: 505). The following sections provide examples of two different strategies for biotechnology innovation by national actors. First, the firm Nidera uses scale and experience to develop new technology based on earlier licensing agreements. Second, the Rosario Biotechnology Institute introduces new public-private linkages in order to bring together locally embedded assets and innovation capacities.

5.6.2 From licensing to innovation

The importance of scientific and codified knowledge in biotech facilitates technology transfer over larger distances and provides opportunities for innovation actors to build on already existing knowledge and innovations. Indeed, incremental innovations are thought to be just as important for long term social and economic change as radical innovations (Fagerberg 2005). The first decade of biotechnology in Argentina was featured by innovations brought in from abroad through multinational corporations and licensing agreements. However, recent initiatives indicates that national actors are entering the market for leading edge technology, as a result of enhanced technological capacity and altered conditions for investments in the area. As argued by one informant:

> Lately, some groups with private investors have appeared that claim to do developments. This results on the one hand from the changed attitude of the government towards research promotion. And on the other hand the attitude of national commercial groups has changed as well, once the profitability of biotechnology had been proved. Because, let's say that the last

> years have manifested the profitability of the principal event, the [herbicide] resistant soybean. Which has been really exceptionally successful.[74]

The agro-industrial company Nidera is one of few Argentine biotech actors conducting independent research. Their laboratories mainly administrate projects independent of partners and agreements, but lab work always makes much use of freely available information (codified knowledge). Whereas smaller and inexperienced firms are unable to profit from these information sources, my lab informant posits that Nidera's advanced lab infrastructure and large budget allows them to build new innovations on already existing knowledge in the form of publicly available data[75]. This resonates with the emphasis on codified, scientific knowledge in biotechnology, where research results conveyed from other sources complement internal R&D. Participation in networks that extend beyond the local is a further aspect in that “spaces of knowledge [...] draw on far more than spatial proximity” (Amin and Cohendet 2005: 470). As upheld also by a Nidera market coordinator, firm consortia and collaboration with the INTA and foreign universities constitute an important part of their knowledge fundament[76]. The company has since the introduction of GM technology been a pioneer and is now market leader in soybean seeds (Trigo and Cap 2006). Along with a strengthened position their strategy has also shifted from *licensee* to *licensor;* until 4-5 years ago Nidera was primarily buying or licensing technology from other market leaders like Monsanto and Dow. Now, however, they are granting licenses to others for the use of their own developed genes[77]. The role of intellectual property rights for technology transfer and innovation has been discussed earlier. Suffice to mention Branstetter *et al* (2005)'s argument of technology transfer inducing innovation, as recipients build R&D competence by modifying imported technology. Thus Nidera's development is resonant with the literature. By acquiring breeding programmes and licensing technology the company has established a sufficient genetic base for innovation activities internally[78].

In fact, according to one of their breeders, Nidera works in a way that is diametrically different from the multinationals. Rather than modify standard technology developed abroad, they focus their efforts on specifically designed varieties complying with local needs and challenges. Nidera started out as a technology licensee from big foreign corporations, establishing a technological capacity on which to build independent R&D. Their long history in the agricultural market and steady growth has enabled them to acquire a position as technology leader based on knowledge and capital resources. In fact, in the words of one of their market coordinators:

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74 Patent adviser, interview January 2008
75 Biotechnologist, interview December 2007
76 Coordinator Nidera, interview December 2007
77 Biotechnologist, interview December 2007
78 Biotechnologist, interview December 2007

> Nidera Argentina closes the cycle of grain production, fertilizers and agrochemicals, trading and exports, breeding and crossing of varieties, processing... an entire cycle, a chain. Nidera is one of the few companies, if not the only one, that completes this entire cycle.[79]

By moving from adaptation to innovation Nidera has simultaneously taken on many of the same strategies as the foreign MNCs. Acquiring research programmes and making use of formal and informal sources of information and knowledge are complicated tasks for small and inexperienced firms. As such, the company contributes to a further consolidation of the corporate dominated structure of agro biotech (as argued by Varela and Bisang 2006; Cooke 2007). The case can nevertheless be regarded as redefining Argentina's capacity to innovate, because of their shift from importer to developer of technology and their key focus on local conditions.

5.6.3 Biotechnology in public-private ventures

The Rosario Institute for Agrobiotechnology (INDEAR[80], henceforth the Biotechnology Institute) is initiated by the two private firms Bioceres S.A and BioSidus S.A. The project is sponsored by the Argentine No-till Association[81], and counts on close cooperation with the the National Technology Council. A proceedings on the initiative states that the objective of the Biotechnology Institute is to "develop research oriented at solving problems of high economic and innovative impact in the agricultural sector. The Institute intends to establish a new model of strategic integration between the public and the private sector within the science-technology realm" (INDEAR 2008). The aim is to perform both short-term investigations in collaboration with external firms and institutions, as well as more extensive R&D programmes primarily with public sector laboratories. According to an informant in the institute's administration, the project aspires to build linkages with foreign R&D actors in order to bring in technological developments that can be adapted and commercialised in Argentina. To date no external institutions have joined the project and primary emphasis remains on national agents. This reflects the general aim which is problem-solving of local and regional character: "*Basically, we'll develop GMOs in search for improved agricultural yields*"[82]. The institutional vision operates with the three following lines of focus. First, strategic research with a timespan of five to seven years primarily within genomics and plant and animal breeding. The overall objective is the "generation of new knowledge that permits the capture of economic value through patents and licenses" (INDEAR 2008). Second, directed research over three to four years focuses on applied research, generating products that can be rapidly brought to the market. Within this strand the institute opens up for licensing external technology that can be adapted to local conditions. The third line centres on contract research and services requested by various economic

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79 Coordinator Nidera, interview December 2007

80 Instituto de Agrobiotecnología de Rosario

81 Aapresid (Asociación Argentina de Productores en Siembra Directa)

82 Coordinator INDEAR, e-mail correspondence October 2008

agents, with a time range of six months to three years and working teams formed on an ad hoc basis. The report further states that researchers and personnel will be recruited through the Technology Council's exchange programme *Researchers in firms*[83], and through specific agreements with the Agricultural Institute and the various universities. The Biotechnology Institute also plans to contract expert specialists in particular fields, “giving special priority to the repatriation of Argentine and Latin American researchers currently based abroad” (INDEAR 2008). This latter point is interesting considering the large share of expatriated persons mainly from the academic sector, contributing to the deficit in qualified personnel in the biotech sector as discussed earlier.

Departing from the agreements between the two private firms and the Technology Council, the Biotechnology Institute aspires to constitute a new innovation model of public-private relations. It emerged from the recognition that public investments, particularly in infrastructure and human resources, are crucial for commercial activity. At the same time, the business side views public-private cooperation as strategic to fulfil their objectives. The following statement concerning the project illustrates:

> We decided to do the project with the Technology Council precisely to create a platform that permits us to accomplish our projects, and in addition become a node in a global web.[84]

Thus the project exemplifies the much discussed reorientation of innovation studies claiming that inter-organisational collaboration is increasingly important for the production and transfer of knowledge. As shown, this is the basis of NIS. Also Etzkowitz' Triple Helix model highlights the need for firms to draw on universities as sources of knowledge. Arguably, the university as a teaching institution is a key player because “the turnover of students insures the primacy of the university as a source of innovation” (Etzkowitz and Leydesdorff 2000: 118). However, the model also assumes alterations within the sector towards integration of teaching and research, a dubious designation for the Argentine case where R&D to a large extent has been confined to the Technology Council and other institutions (see Katz and Bercovich 1993). My informant in the Biotechnology Institute clarifies that the project emerged as a response to unsatisfactory cooperation with the university sector:

> The institute was initiated after Bioceres had led projects with the universities for two years. When they saw that this outsourcing wasn't working neither in terms of time use or form of the agreement, the Biotechnology Institute was launched in association with BioSidus.[85]

The statement demonstrates the inability of the university sector to comply with the needs and

[83] http://www.conicet.gov.ar/VINCULACION/investigadores_empresas/index.php, 30 October 2008
[84] Executive biotechnology firm, interview November 2007
[85] Coordinator INDEAR, e-mail correspondence October 2008

interests of private business. The institutional set-up of the institute thus reflects private sector endeavours to access public sector resources in a more effective manner. As clarified earlier by one informant (section 5.3), bureaucratic obstacles in the university sphere cause researchers to engage in other projects or entities[86]. As the Technology Council performs several core university tasks, this justifies the choice of the council as the main source of research personnel.

As a recognition of the contribution provided by the Technology Council, it is stated in the institute that intellectual property and royalty incomes will be shared with the council according to their participation in each project. However, findings presented earlier suggest that the conditions for soliciting IP protection in Argentina are far from optimal. From an innovator’s point of view, inconsistencies in the legal framework make it difficult to exclude third parties from using the variety in question to create new developments. This situation potentially complicates the ability for stakeholders to secure economic profits from their innovations. On the other hand, by accumulating a critical mass of researchers and relevant institutions, the Biotechnology Institute may spur innovation synergies and stimulate further developments in the biotech sector (Asheim *et al* 2007). Considering the key role of the Technology Council in the project, it is likely that interests beyond immediate commercial gains are relevant, concomitant with Coenen (*et al* 2004) arguing that public sector research is more devoted to open science policies. Revisiting the notion of subsystems proposed by Cooke (*et al* 1998, in Cooke 2007), the establishment of the institute assumes the role of articulator between the examination phase (scientific research in the Technology Council) and the exploitation phase (corporate commercialisation objectives). Evidently, linkages with the public sector is crucial for the project's success, and although long-term relationships are still of abstract character public-private cooperation is designated as

> ...strategically very important. (...) We have formed a network between the Biotechnology Institute and eight public institutes belonging to different universities and the Technology Council. From this will emerge research on soil biology. We're still in the preceding phase of our independent R&D activities.[87]

As earlier mentioned, the institute has close connections with the No-till Association, which is made up by a network of farmers. This affiliation is likely to provide the actors with a channel for smooth technology transfer to the agricultural sector. In the subsequent section the importance of producers is scrutinised more thoroughly, seeking to redefine the role of the farmer community in seed biotechnology innovation.

[86] Biotechnology professor, interview January 2008
[87] Coordinator INDEAR, e-mail correspondence October 2008

5.7 Aligning farmers in the innovation system

The previous sections have reviewed the role of public entities and private business for the development and promotion of seed biotechnology in Argentina. Reforms in the regulatory framework smoothed the introduction of new GM events, and private business has met little resistance from political circles. Although public universities and research organisations constitute the main source of qualified personnel in the biotech area, lacking resources and failure to appreciate commercialisation objectives has vested all leading-edge and innovative research in the private sector. In general, Argentine firms have focused on adaptation and modification of imported technology. However, along with enhanced knowledge and innovation capacities local biotech actors turn towards the public sector for cooperation and joint problem-solving.

Not underestimating the crucial position of actors directly involved in development of new technology, the Argentine case suggests that the rapid success of seed biotechnology must be explained also with factors beyond the conventional innovation system. As we shall see, conflating biotech with other interests serves to unite actors across sectors in efforts to achieve common aims. Thus, the multi-faceted characteristics of biotechnology aids to couple it with the success of as diverse areas as no-tillage and increased productivity, environmental preservation, social equity and not least technological advancement, innovation and economic growth. Through active eloquence from several actors about the positive contributions of biotechnology, commercial objectives surpass the corporate sector and integrate with other sectors.

5.7.1 The farmers convinced

Wagner (1998) brings our attention to the two-sided dimension of innovation by referring to it as an outcome of “science push and market pull”. Hence the crucial point is convergence between new scientific creations and consumer demands. As illustrated by the massive acceptance of GM technology by Argentine farmers, the advantages of transgenic crops for producers were fundamental for the rapid and wide-spread diffusion. As the executive of a local seed- and chemicals firm put it:

> What (GMOs) did for the Argentine producer, and for the Argentine agro was really save it. And the entire country. It gave it a huge competitive capacity: explosion of the soybean production, at low costs and product application. Earlier one used more or less 4-5 products, chemical cocktails, high costs. At least 50 dollars in agrochemicals, and a lot of contamination.. And now: one single herbicide which is rapidly absorbed by the environment, with fewer applications and a saving of 40 dollars per hectare.[88]

This assertion reflects the general opinion that farmers account for the primary demand for agro

[88] Executive input firm, interview November 2007

biotech, in stark contrast to the claims by many biotech opponents that multinational corporations construct dependence upon their products (*e.g.* Shiva 2000). The above-mentioned “push and pull” mechanisms assume interactive contact between suppliers and users of technology. Looking into the roles of and relations between the different agents may also yield better understanding about the factors stimulating new biotech inventions. Naturally, technology providers receive a great deal of information simply through analysing market demand. User-producer connections are often given high importance in the general literature on innovation (Asheim and Gertler 2005), but the issue is too often underplayed in studies on innovation systems and biotechnology. Instead, focus is directed towards biotech firms and large corporations, university and R&D milieus, as well as policymakers dealing with science and technology. As chapter 3 shows, the frameworks of NIS, Mode 2 and the Triple Helix all seek to define and revise the interplay between these actors. Although new biotechnology to a large extent is derived from scientific research and laboratory experiments (*c.f.* its analytical knowledge base), subsequent stages such as field trials are indispensable both for the control and further commercialisation of a product. Furthermore, the commercialisation objective in the industry manifests that clients and market situation is crucial. This section considers how farmers are key for the success of agro-biotech in the Argentine context, therefore seeking to transcend the common view of agricultural producers as passive recipients of technology.

In Argentina the seed industry has established close relations to farmers' associations, and also gains contact with producers through local distributors of seeds and chemicals. As mentioned in relation to the possible acquisition of a local seed supplier by Monsanto, the wide-reaching contact network is an asset that the multinational seeks to control. In addition, the largest corporate technology providers establish agreements of seed multiplication with individual farmers, underlining the role of direct relations with the producer side for the industry. The country's position as a global number 2 in GM production indicates that farmers are widely convinced of the positive aspects of biotech. The role of farmers for biotechnology prosperity in Argentina is thus dual. First, they are fast adopters and hence promoters of GM crops. Second, they actively communicate needs and desires to technology developers through various channels. The 2005 UPOV report suggests that the market share of new, protected varieties is an indicator of the variety's success, or value to the farmer. As stated by Trigo and Cap (2006), the producers are perceived to be the primary beneficiaries of the GM revolution in Argentina, especially in soybean. Between 1995 and 2001, the share of protected varieties increased from 35 to 94 percent of total sales of soybean (UPOV 2005). This indicates that improved property protection also leads to increased use of the technology, concomitant with Branstetter *et al* (2005) who show that royalty payments increase when patent regimes are strengthened. All in all, the evidence calls for a revision of the role of farmers in biotech innovation in the Argentine context.

The executive of a licensee firm underlines that the needs of each individual farmer is a key concept in the input negotiation. In order to distinguish themselves as the best supplier, the firm works with local distributors that represents local and personal, indeed tacit, knowledge:

> A company has knowledge about the products and the general sides of the different regions. But one thing is to know the soil and the average rainfall of a zone, another thing is to know the idiosyncrasies of the user. (...) So we work with our local distributor, who sees from our assortment which product is more convenient for this particular producer.[89]

Establishing and maintaining good relationships with farmers and middlemen is the backbone of the firm's commercial strategy. The firm has further chosen to specialise in GM seeds licensed from Monsanto and other market leaders, thereby lending them a reputation as a stable provider of leading edge technology. Being an small firm working through local networks, they are clearly efficient in bringing out biotech solutions to small-scale and rural market segments. Thus, adding to the mutual benefits of collaboration, such partnerships simultaneously function as a transfer channel of externally developed technology.

Farmers' associations and cooperatives also constitute a contact point between technology developers and producers. As such, a representative in a national cooperative union explains how they function as a technology diffuser.

> Our sector is very apt when it comes to technology incorporation. Very often the technology advances much faster than our ability to incorporate it. So, we are diffusers of this technology and we have to be well informed about the consequences it can or cannot bring.[90]

A variety's pathway to the farmer goes through field trials and evaluations conducted by the cooperative. According to my informant, their agronomists perform local and regional tests in order to obtain genuine information about each crop. The results are later communicated to members and employees through internal magazines, the superior objective being, in the words of the informant, that *"the available technology is within the reach of all our members"*. Considering their position as a cooperative, they are clear on not signing agreements with any firms. Relationships with the corporate side are still described as excellent, and the organisation is accordingly *"distributor of practically 99% of the suppliers in Argentina"*.

As the positive experience of both cooperatives and supply firms demonstrates, there is little resistance among farmers against GMOs and biotechnology. Indeed, a private sector informant explains that

> ...we work a lot with farmers because the Argentine producer is already convinced. If you look at the rates of adoption of transgenic crops in Argentina, it's very high. (...) What this

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[89] Executive input firm, interview November 2007
[90] Representative cooperative, interview November 2007

states is really that it's convenient for the farmer to use it.[91]

5.7.2 Technology and profitability

Clearly, economic profitability is the key to understanding why farmers have adopted GM technology so openly. The advantages of investing in such shifts are further accentuated when considering the synergistic effects of biotechnology and other agricultural technologies. First and foremost, the framing of biotechnology as a component of a *technology package* that also integrates specialised agrochemicals and no-till production indicates that converging interests in this way is important. Similarly, GM biotechnology, agrochemicals and no-tillage has been coined a “matrix for development”[92]. Today the no-till system is used in about 70 percent of Argentina's agriculture, having increased steadily from less than 1 million hectares in 1991 to nearly 20 million in 2005[93]. Tilling is traditionally used as a method for weed control and the mixing-in of chemical input. However, over the last decades much research has showed that negative effects and soil erosion can be avoided by reducing or suspending tillage. No-tillage practice requires large single-crop areas and expensive, specialised machinery, and efficient pest-control. According to Pengue (2003), soybeans account for the major rise in chemicals applications in Argentina, and glyphosate further represents 37% of herbicide use in the agricultural sector. In an earlier paper, the same author argues that GMOs in Argentina are particularly associated with RR soybeans in no-till production. On the one hand this has aided to reduce and reverse erosion, while it on the other hand leads to increasingly higher agrochemicals input (Pengue 2001).

GM technology has gained such popularity because it facilitates higher yields and lower input costs, easing the shift to an industrial model of agricultural production. Resonant with the general viewpoint that the productive sector is positive towards biotechnology, a visit to a large scale production estate revealed that they have actively incorporated new biotechnology since its introduction. In fact, the farm counts on close relationships with Monsanto and devotes a rather large share of their land to seed multiplication for the corporation. The linkage to Monsanto dates back years prior to the GM launch in 1996, centring around agreements of maize and soybean production for domestic sales and exports[94]. All contact and negotiation is done directly between the two parties, and the farm management reports excellent relationships with the corporation. According to the estate manager, the farm is one of several seed multipliers in the area, nevertheless

91 Executive biotechnology information office, interview November 2007
92 Firm representative, conference lecture Buenos Aires, November 2007
93 Aapresid presentation, 2007
94 The farm's major business is seed multiplication of maize, where Monsanto designates the variety desired for each season (generally transgenic hybrids). Because the maize plant has both the male and the female gender, the top flower (male) must be manually cut off in order for the cross pollination to take place. This is normally done by day-workers imported from the northern regions of the country, contracted by Monsanto through an employment agency.

being one of the largest. Thus he stated that *"Monsanto is probably more dependent on us than we are on Monsanto"*[95]. However, the farm employees I spoke to note pressure to adopt new transgenic technology for both multiplication and production uses. Particularly they refer to a newly developed variety of RR (herbicide resistant) maize, leading to a discussion about the reasons for the massive push to get the new technology to the market. The informants link the issue to a possible prohibition of a highly toxic fertilizer that has been found to contaminate ground water in the USA. The new maize variety accordingly allows diminishing the use of fertilizers. Although the chemical is less widespread in Argentina, it is suggested that the RR maize is an attempt by Monsanto to be ahead in the market with a viable substitute.

As the example shows, the close relationships between biotech corporations and agricultural producers offer a direct transfer channel for new innovations. Through seed multiplication agreements with large production units new varieties are easily tested out, multiplied and commercialised, again highlighting the central role of Argentine farmers in accepting and diffusing agricultural biotechnology. However, due to this less than direct contribution to innovation activities, the role of agricultural producers in biotechnology is often underplayed. Their position as more than mere end-users is nevertheless clear when reviewing the importance of technology diffusion for providers, and when considering farmers as active market players. Eight of my informants explicitly stated that they didn't note any opposition against GM technology at all. Some agreed that scepticism was higher in the early period after the introduction, but found that this had rapidly fainted away. Seed supply firms in particular point to sales figures to demonstrate the lacking opposition, as demand for conventional non-GM soybeans is practically zero. Again, Argentina as an agricultural producer makes the biotechnology issue uncontroversial:

> The one who is against transgenics is the consumer, not the producer. We are on the producer side. In our case we're a producing country. [...] And well applied technology is always good.[96]

5.8 Redefining the innovation system

This chapter has presented the national innovation system for seed biotechnology in Argentina. By drawing on theoretical insights into innovation dynamics and biotechnology, the actors in the system and the relations between them have been described. Departing from the the illustration of the Argentine NIS case (figure 3), I have discussed the roles of the different organisations and institutions for developing the country's biotechnology sector. The concluding chapter will provide a detailed picture of my findings. To sum up, two major points can be highlighted. First, public-

95 Estate manager, farm visit January 2008
96 Representative farmers organisation, interview November 2007

private cooperation is increasingly important for local industry as biotech firms build up technological capacity. However, the university sector remains an unattractive R&D partner as other public research organisations are perceived as more business-oriented and efficient. Second, farmers occupy a central role in the success of GM technology in Argentina. By acknowledging that agricultural producers are more than passive receivers of seed biotechnology, our understanding for the dynamics in the country's NIS can be enhanced. Figure 6 is an elaboration of the initial model of the Argentine NIS, and depicts these two trends as key factors in the seed biotechnology industry.

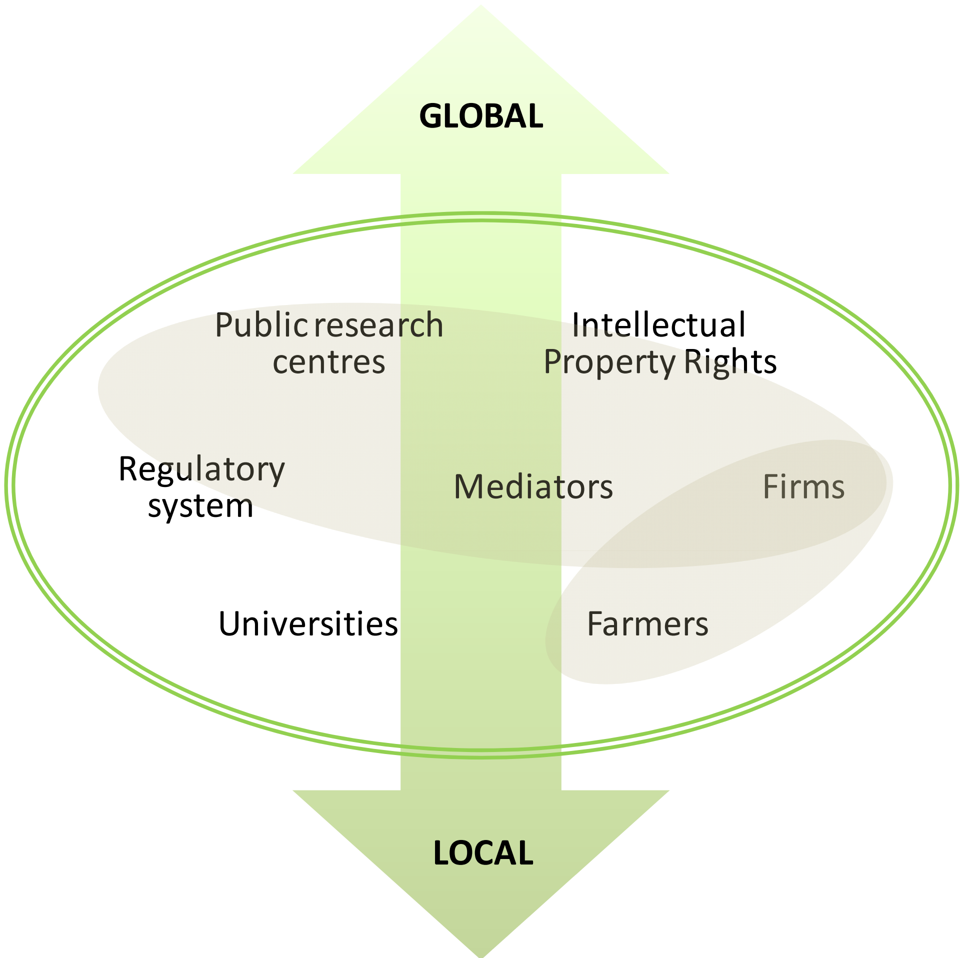

Figure 6: New relationships in the Argentine innovation system

6. CONCLUSION

I have in this thesis sought to analyse the dynamics of seed biotechnology innovation in Argentina. The starting point of the project was a recognition of the particularly strong position of the technology in the agricultural sector, and its rapid diffusion over the last decade. My studies show that the nature of the relations between the actors involved are of prime importance for the success of GM technology, and even more so the links between public sector agencies and private business. Thus, the research questions answered in this review are as follows.

1. How are the relations between public and private organisations constituted in Argentina's seed biotechnology sector?

2. Why are the relations structured this way?

In order to grasp the complexity of the interaction within agro biotechnology I map the actors in the system (see figure 3) and describe their respective roles. Reviewing the institutional changes that have been made to facilitate the adoption of GM technology also demarcate the settings in which innovation efforts take place.

6.1 Sectoral integration and public-private networking

The starting point for analysing the relations between the actors in the Argentine innovation system is figure 3 presented in the analytical framework. The model is based on a mental picture of the main agents involved and how they work together; tantamount to the organisational taxonomy called for by Edquist and Johnson (1997). Concomitant with the IS approaches, innovation processes are shaped by the quality of the relationships between these organisations and by the broader institutional structure. By making a main distinction between public and private organisations, the authors propose studying the roles of different organisations within a particular innovation system keeping in mind that these vary substantially. This is a fruitful strategy also for the case of Argentina, where the public and private sectors differ both in set-up, tasks and core objectives.

6.1.1 Agents in biotechnology innovation

Relevant public organisations in Argentina's agricultural biotechnology sector can be placed in two chief bulks relating to science and education on the one hand, and regulation on the other. First, universities and public research organisations are directly involved in knowledge enhancement and technological development. Second, the country benefits from a well-functioning regulatory framework for agro biotechnology, which emerged after a series of tailored reforms to smooth the introduction of new technology (see figure 4).

Within the private sector, firms and firm-sponsored associations are the primary innovation actors. In addition, farmers and farmer organisations are active players in the biotechnology field, since they are first-hand recipients and users of new seed technology. NIS literature maintains to a large extent focus on firms, as Edquist and Johnson (1997: 58) stating that "the most important components among the private innovation relevant organizations are, of course, the firms". The analysis of seed biotechnology in Argentina has shown that firms depend on external sources of experience, knowledge and capital, in the form of other firms as well as public research organisations. Also, intermediaries (first and foremost private interest organisations and coordination entities) are shown to be crucial for securing the strong position of biotechnology in agriculture and society as a whole, and for establishing close links between innovation actors.

6.1.2 Relations between public sector agents

The principal actors in the public sector are universities, the Agricultural Institute and the Technology Council. Earlier studies on innovation in Argentina suggest that public R&D entities fail to coordinate their work and to be drivers in technological development (Katz and Bercovich 1993; Correa 1998). My empirical material is clear on the marginal role of universities, as particularly business representatives perceive them as confined to teaching and elementary research. Inefficient university administration further impede research efforts. The majority of existing research- and technology transfer agreements are typically oriented towards the private sector, as this is viewed both as more lucrative and as more stimulating for innovation.

A primary public sector task of crucial relevance for biotechnology innovation is the regulation and control of new seed technology. As opposed to the situation in public research organisations, the three regulatory bodies plus the Seeds Institute that grants IPR are well coordinated and succeed in making the regulation process smooth and efficient. Consequently, new and approved GM seeds rapidly reach the market, and property rights (although being weak) do function as a profit incentive for innovators.

6.1.3 Relations between private sector actors

The 1990s as the first decade of seed biotechnology in Argentina was characterised by adaptation of imported technology to local conditions. As upheld by Cooke (2007), agro biotechnology is, as opposed to the pharmaceuticals industry, dominated by a handful of large corporations. This must be seen in relation to the potential for incorporating biotechnology in the food value chain featured by a high degree of vertical integration (Dicken 2007). The general dominance of global MNCs in seed biotechnology elucidates the position taken by local business towards larger corporations. Being unable to compete in terms of costs, knowledge or experience, small firms generally choose a collaborative strategy seeking to establish themselves as allies with foreign consortia. However, a main feature of this non-competitive stance is licensing as a means to access technology. Thus, the Argentine biotech industry considers direct linkages with global technology developers as a key source on which they can build their proper technological capacity.

Both local and foreign firms are active participants in a number of private sector associations that on the one hand function as coordinators of interests and efforts, while on the other serve as effective promoters of agricultural biotechnology towards other agents and milieus. My studies show that specific mediator organisations that bring together all actors along the soybean and maize value chains strengthen relations between as diverse actors as research organisations, local and international commercial firms and farmers. These private sector associations also maintain close links with each other. By offering a dedicated space for cooperation and problem-solving, these private sector associations open for the articulation of short- and long-term objectives, and facilitate coordinated activities for promoting agricultural biotechnology in the country.

An important feature of the Argentine biotechnology sector is the position of the farmer community. Whereas IS and biotech literature focuses on the interaction between research centres and firms, my analysis shows that agricultural producers have played a key role in the rapid propagation of seed biotechnology. Rather than conceiving of them as passive end-users of new technology, biotech firms invest heavily in establishing good relations with farmers through various channels. First, technology developers depend on direct alliances with big producers for multiplication of seeds and adaptation of standard technology to local conditions. Second, seed suppliers access farmers through cooperatives and federations which convey information and recommendations to their members based on productivity tests and field trials. The third channel through which biotech firms communicate with farmers is by means of locally based distributors. This is considered vital for supplier competitiveness because it enables a combination of leading edge technology and knowledge about local conditions. Both small firms and large multinational corporations clearly see notable value in establishing close ties with the productive sector, resulting in this use of extensive contact points between technology providers and farmers.

6.1.4 Relations between public and private sector actors

NIS scholarship and the analytical framework presented earlier casts light on how innovation is created in the interplay between actors concerned with the production and exploitation of knowledge. Public-private networking is thus central. The simplification of the regulatory process has eased private firms' ability to bring new products to the market. The Seeds Institute's practice of letting IPR applicants provide their own information further illustrates the relation of trust between the biotech industry and official entities. First, this helps promote GM technology in agriculture and other areas of the society. Second, it stimulates collaboration between public and private organisations. As explained earlier, biotechnology firms and corporations collaborate about information- and lobby activities through specifically designed organisations. Contact with the political system is coordinated through the Association for Seed Suppliers, and both firms and private sector interest organisations experience positive attitudes towards biotechnology from government- and public administration. Furthermore, corporate interests are communicated to teaching institutions, NGOs and other civil groups through information offices with main objectives in promoting biotechnology. This illustrates how facts and interpretations from commercial actors are incorporated in the formation of public opinion and policymaking.

Recent scholarship has exhibited increased interest in the university as a driver in innovation and technological advance, more so in the biotechnology sector which builds directly on scientific knowledge. The Argentine seed biotechnology sector carries many of the features addressed in the literature, and this study shows that cross-sectoral collaboration is increasingly prioritised in both public and private organisations. However, the universities play but a minor role in the generation of new biotechnology. Sections 5.4 and 5.5 explain how public R&D resources are concentrated in alternative public research centres like the Agricultural Institute and the Technology Council, exemplified by the Biotechnology Institute of Rosario (see section 5.6.3). In general, business representatives find universities to provide little if any relevant research. Both universities and other public research centres are criticised for lacking the ability to innovate, but the industry finds it increasingly important to take use of their skills and expertise. Likewise, public research organisations view partnership with firms as an access point to more advanced technology, while simultaneously stimulating developments in the country's agricultural sector.

6.2 New relationships for new innovation

This study shows that local firms tend to rely on external influences in the form of large multinational corporations in order to access technology and innovation stimulus. However, the dominance of global enterprises is not unbiased, as local knowledge and experience are key constituents in adapting standard GM technology to local conditions. Furthermore, the Argentine biotech industry seeks increasingly close relationships with other national actors from the private and public sectors. In the following I will account for the principal reasons for the current systemic set-up, and in short discuss the implications this has for innovation processes in the sector.

6.2.1 The public sector: insufficient resources and poor coordination

The poor coordination between research groups in the public sector is to a large extent linked to the weak position of Argentine universities. This is according to Katz and Bercovich (1993) a result of politically motivated relocation of research activities to other institutions, mainly the Agricultural Institute and the Technology Council. It is likely that focusing R&D in these institutions facilitated stronger government control according to current priorities. Scarce resources also lead university groups to compete for funding and avoid information sharing and "open science" practices. Delinking the two areas of research and teaching has further exacerbated the situation, resulting in the university sector being unable to perform groundbreaking research. Poor financing constitutes a barrier to research and innovation activities, making public research organisations dependent upon commercial activities. The surge of public-private collaboration should be seen in light of this.

6.2.2 The private sector: from adaptation to innovation

Clearly, the private sector constitutes the main impetus for biotech innovation in the Argentine agriculture. Because global corporations are leading in GM technology worldwide, local industry has since the 1996 launch favoured such close and collaborative vertical linkages. This may be considered an access point to foreign markets for Argentine innovators who aspire to export their technology. More importantly, asymmetrical financial and technological power relations make small firms avoid direct competition, while alliances with multinationals at the same time form a channel for external input – tantamount to Bathelt *et al* 's (2004) term *global pipelines.* However, as shown in the analysis, the technology is not implemented *as it is,* but undergoes substantial adaptation to local conditions. This explains why national firms claim a key role in the sector, as they integrate imported technology with experience from national and regional levels. It also highlights the importance of localised knowledge embedded in the local production and thus the farmers. By using foreign partners as a technology source, Argentine firms build a technological base and initiate internal learning processes. The seeds company Nidera illustrates how acquiring a sufficient stock of genetics through licensing and open source information can lead to enhanced R&D and innovation capacity. However, the case also shows that Nidera's size and vast experience in the agricultural input market enable them to take use of codified knowledge that smaller firms cannot. Local collaboration strategies and horizontal integration thus arise as a viable alternative. Whereas Bathelt *et al* (2004) argue that some sort of local buzz will arise almost as a necessity, this study reveals that firms in Argentine seed biotechnology actively invest in coordination and collaboration with other local actors. Various private sector organisations fulfil important tasks in this respect, such as political lobbying, integration along crop value chains, and pro-biotechnology information towards civil society and policymakers. In addition, information, knowledge and technology is transmitted through direct firm-firm contact. In total, Argentina's biotech sector is experiencing a shift of focus from *modification* to *innovation.* Hence, firms and actors increasingly shift attention from global corporations as technology providers towards mutual support and interaction with other national agents.

As mentioned, the fact that the first decade of agro biotechnology in Argentina was characterised by technology adaptation to local conditions explains why agricultural producers occupy an influential role in the biotechnology sector. Why is it that both global and local firms stress good relations to farmers in Argentina? First, GM technology cannot be studied irrespective of its productive foundation. Agriculture is indeed an end-user, but any successful technology must take into account the potential, constraints and idiosyncrasies of the local environment. Farmers are not passive receivers of new technology, but make strategic choices according to self-interest. Evading scepticism towards GMOs is therefore indispensable. Strong bonds with farmers and producer associations are further very valuable to biotech providers, which see it as a direct channel for the promotion of their products. The importance of studying biotechnology within the context of agricultural production is accentuated also by the potent synergies between GMOs, agrochemicals and no-tillage, earlier termed a *technology package* or *matrix for development* (section 5.7.2).

6.2.3 Public-private interplay to build innovative capacity

The assertion that private industry has succeeded in forwarding biotechnology as uncontroversial in the agricultural sector sheds light on the collaborative structure of public-private relations. The regulatory framework regards GMOs as environmentally safe and economically profitable, something which can be explained by the effective broadcasting of the technology and its rapid acceptance among farmers. Argentina is first and foremost an agricultural producer, having profound implications for public policy. Limited resources in the public sector also cause government offices to collaborate with private actors for information and control. Poor economic assets is equally an element in the university sector, exacerbating their already unattractive position as R&D partners for the biotech industry. However, biotechnology's high reliance on scientific knowledge makes linkages with public research organisations almost indispensable, more so for young and inexperienced firms with limited technological and economic resources. Because public research efforts to a large extent is concentrated in institutions like the Agricultural Institute and the Technology Council, private business instead orient themselves towards these to access qualified personnel and public funding. Correspondingly, public research centres explicitly foment relations to industry in order to participate in and stimulate biotechnology innovation. Along with the stronger focus on innovation, the issue of intellectual property rights surfaces. My material is clear on the dissatisfaction among breeders with the current system where plants are excluded from patenting, thus leaving new innovations easy to copy. In line with Yang and Maskus (2003), my informants in the biotech industry stress that improved IPRs are critical to stimulating innovation and R&D investments. Global linkages remain important by providing input and constituting a pipeline to external markets, but firms increasingly seek local partners from the private and public sectors as a means to stimulate national innovation.

6.3 Broadening the perspective

6.3.1 The contributions of the study and the transferability of my findings

In chapter 2 a short review of case study research was provided, arguing for conceptualising seed biotechnology in Argentina as a case of a *national innovation system for agricultural biotechnology*. This thesis has accordingly focused on the nature of the relations between actors and interests in the public and private sectors. A general note is that most literature on biotechnology and innovation concentrate on the pharmaceuticals industry, leaving agricultural and seed biotechnology unexplored in comparison. This study has nevertheless drawn on general ideas and findings that are common for the two in order to reach an adequate theoretical understanding about the phenomenon. Furthermore, because Western economies are by far the most innovation intensive, most empirical studies are from countries or regions in North-America, Europe or Japan. That being the case, the analysis of my material has revealed some major discrepancies between existing studies and the Argentine context, especially in the role of universities and public institutions concerning R&D and innovation activities. Also, farmers and agricultural producers have appeared to be indispensable for the success of GM technology, something which is seldom discussed in the IS literature. Rather, existing research tends to focus on the analytical and scientific foundation of biotechnology. A third finding is that IPR receive increased attention as local industry moves from technology importation to innovation. IPR is certainly acknowledged as important for innovation, but little consideration is generally devoted to it in biotechnology studies. It is likely that the current weak system of patents and property rights in Argentina make biotech agents more aware of the issue, whereas Western countries count on standardised frameworks more in line with the requirements of the industry.

The mentioned mismatches between the Argentine case and current scholarship on the theme have implications for the transferability of my findings. Clearly, the case differs in many respects from other contexts in which biotechnology innovation takes place. Thus it is necessary to reflect on the characteristics that are relevant and interesting for comparison in other places and times. First, I argue that Argentina's biotechnology industry is an example of a sector and economy *in transition,* that aspires to a stronger position on the global technological market. Challenges concerning insufficient resources for public research can be expected to exist in other middle-income countries and unstable economies. It has accordingly been an aim for this project to enhance the understanding of innovation dynamics outside the Western frame of reference. Second, reflecting the general underrepresentation of agricultural seed biotechnology in innovation literature, the Argentine case can provide new insights of relevance for areas where this is a priority industry (as opposed to pharmaceutical biotechnology). Third and related, Argentina is first and foremost an *agricultural producer,* something which explains the powerful rank of farmers and their influence on the biotechnology industry. Thus, this group will probably occupy a determining role also in other countries that rely heavily on agricultural exports. In addition, I hope that this study can contribute to a more nuanced perspective on the role of farmers in agricultural biotech innovation more broadly, as it is highly problematic to isolate the technology from its context of utilisation.

6.3.2 New paradigms in agriculture and research?

The closing part of chapter 5 argued for the inclusion of farmers as indispensable actors in the agricultural biotechnology sector. The notion of *technology package* was mentioned, suggesting that biotechnology forms an element in a broader structural shift together with agrochemicals and no-till production methods. One informant pinpointed this as a *"change of paradigm*", conceptualized as *"modern agriculture"*[97]. Changed global conditions are deemed the principal driving force, as increased productivity and higher production scales are necessary to remain competitive. A problematic aspect is, however, that small and medium scale producers are pushed out of the system, and the remaining compelled to shift from conventional to GM production because of the lower input costs and higher profits[98]. Lyson (2002) concordantly describes two fundamentally dichotomous views of agriculture. First, conventional agriculture builds on a rationale of productivity and efficiency, incorporating agricultural biotechnology as a natural "next step" towards economically and environmentally sound production. Second and conflicting, sustainable agriculture is a holistic and systems-oriented approach, placing social and environmental concerns at the core. Thus, the focus on *traits and commodities* as opposed to *processes and community* makes genetic engineering inherently incompatible with sustainability. This raises the debate over environmental as well as societal impacts of broader changes in agricultural production. Considering the rapid developments in seed biotechnology, there is a high need for further research on the role of GMOs and the biotechnology industry in the restructuring of farming practices. The

[97] Coordinator No-till Association, interview November 2007
[98] Environmental researcher, interview October 2007

following quote illustrates the difficult task weighing contrasting benefits and principles against each other:

> When you look at Europe and the issue of organic farming, it's very good. Because they can pay for it. It's agriculture for rich people. Now, for the rest of the world who needs to eat we have to try to make it as healthy and as cheap as possible.[99]

Biotechnology thereby becomes a fix for the world's food shortage; a second *green revolution* where scientific revolutions endow higher productivity. Yet, referring to Gibbons *et al*'s (1994) shifting mode of knowledge production, Cooke (2007) notes that the value free and objective fundament disappears when research emerges from the societal contextualisation of science. As biotechnology finds itself in the realm between scientific discoveries and commercial interests, the pivotal question is: *"For* what *and for* whom *are we doing research?"*[100]. The debate was opened by an environmental researcher and critic of the industrialist model of agricultural production of which GMOs are a decisive part. Clearly, there is a need for more and critical scrutiny of the undisputed dominance of commercial interests in the biotechnology industry. Leaving room for ponderation, my informant depicts the issue:

> Unfortunately, what is surfacing now is all from the private sector. The big companies like Monsanto invest a lot of money in development [of biotechnology]. At the global level they are in the lead. Whether what they are selling and commercialising, what they are investigating in, is convenient for all of humanity or not: that is the problem.[101]

[99] Executive input supply firm, interview November 2007
[100] Walter Pengue (GEPAMA), speech at the Spanish Consulate in Buenos Aires, October 2007
[101] Representative farmers organisation, interview November 2007

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Appendix 1: INTERVIEW GUIDE

- General information about the firm/organisation: objective, structure, history etc.
- The history of agricultural biotechnology in Argentina
- The organisation's role in the agro biotechnology sector: research/education/production/commercialisation/other
- The research/technology focus of the organisation. Formulation of objectives and financing of research efforts. What kind of research does the organisation conduct, how and where?
- Perception of seed biotechnology in Argentina and in general, current role of GM technology
- Efforts for enhancing biotech R&D within the organisation and in Argentina
- Impacts of biotechnology for different groups and sectors: R&D/firms/agriculture/others
- The organisation's relations to universities and opinion of biotech efforts in the university sector
- Relations to public research centres and opinion of biotech efforts in public research
- Relations to multinational companies and view of their role in seed biotechnology
- Relations to local firms and view of their role in seed biotechnology
- Relations to farmers/producer organisations and view of their role in seed biotechnology
- General perception of government politics towards biotechnology and R&D
- Perception of the regulatory framework for seed biotechnology in Argentina
- Opinion of the role of IPR for biotech innovation and perception of the IPR system in Argentina
- Perception of biotech R&D in the country. Public versus private funding
- Importance of biotech for trade and exports of agricultural produce in Argentina
- Controversies in biotechnology. Resistance against GMOs in Argentina and its effects on R&D and agriculture
- Perception of environmental- and health aspects of agricultural biotechnology
- Perception of biotechnology in relation to industrial agriculture (agrochemicals, monocultures, land concentration)
- Possibilities for producing biofuels in Argentina and the role of agro biotechnology in this
- The future of biotech R&D in Argentina. Challenges and possibilities
- Aspirations and objectives of the organisation in the country's long-term biotech trajectory
- The future of the agricultural sector in Argentina and the role of biotech in it. Challenges and possibilities
- Comments/suggestions