Vegetable breeding innovation in China and the Netherlands

A study at sectoral, company and project level

Zhen Liu

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Dedicated to my parents and my partner Huole

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1. Introduction

Innovation has become the fundamental driver of competitiveness for companies of all sizes in virtually all business sectors and nations. But companies are no longer able to do all innovation activities alone. It has also become generally acknowledged in the innovation management literature that companies rarely innovate alone, but embedded in dense networks of contacts and collaborations with external innovation partners, such as supply chain partners, universities and research institutes, intermediate organizations, consultants, governmental organizations, and even their own competitors (Granstrand et al., 1992; Gemünden et al., 1996; Spender, 1996; Cobbenhagen, 1999; Omta et al., 2002; Laursen and Salter, 2006; Dodgson et al., 2008b; Batterink, 2009; NSF, 2012). Such innovation networks enable companies to get access to knowledge and resources that they do not possess themselves (Lane and Lubatkin, 1998; Ahuja, 2000; Oliver, 2001; Tsai, 2001; Ahuja and Katila, 2004).

This thesis aims to investigate the influence of innovation networks on the innovation and business performance of vegetable breeding companies (VBCs) in China and the Netherlands. It integrates the analysis at the sector, company and project levels. Studying innovation in the vegetable breeding industry is of great importance as it stands at the basis of the vegetable supply chain. It is well-established and successful in the Netherlands and experiencing transition from a planned to a market economy in China. This study was carried out in both countries from 2008 till 2012. The sectoral innovation system framework was applied to analyse systematically the institutional environment for innovation in vegetable breeding companies in both countries. The Wageningen Innovation Assessment Toolbox was used to collect empirical data from VBCs in China and the Netherlands to identify the key success factors for innovation. Comparison of innovation networks and business performance was conducted within and between the two countries. The results could be relevant for the development of decision-support models for government agencies and VBCs in order to learn how to stimulate innovation in the vegetable breeding industry.

In this chapter, the management of innovation is first introduced in Section 1.1, and then the importance of innovation for the vegetable breeding industry is introduced in Section 1.2. Next the research framework of the knowledge-based view and the research questions is explained in Section 1.3, and finally a brief outline of this thesis is presented in Section 1.4.

1.1 The management of innovation

In 1934, the economist Schumpeter defined innovation as a process of creative destruction, where the quest for profits pushes innovation by constantly breaking old rules to establish new ones (Schumpeter, 1934). Nowadays, it is highly recognized that innovation is one of the major drivers of business success and economic development in the knowledge-driven economic age. Researchers found that innovation makes a significant contribution to economic growth, as innovation is the basis for increasing productivity, both by incremental improvements and breakthrough change (Pavitt, 1969). Furthermore, from the American Management Association (AMA) survey among 1,396 top executives in large multinational companies, it was concluded that more than 90% agree that innovation is important for their company's long-term survival (Jamrog, 2006). Based on the review of 60 definitions of innovation collected from the various disciplinary literatures, a generic definition of innovation, given by (Baregheh et al., 2009), is "*the multi-stage process whereby organizations transform ideas into new or improved products, services or processes, in order to advance, compete and differentiate themselves successfully in their marketplace*".

Innovation is a broad-ranging, complex and difficult issue, which requires managers of innovation to know the different types of innovation, e.g. radical or incremental, and the different levels of innovation. They also need to appreciate the major innovative measures, such as R&D investments and open innovation strategies, and know the different sources of innovation, such as suppliers, clients, universities, technical transfer agencies, academic publication, and professional associations. Furthermore, they need to understand the changing nature of the innovation process. Over the past twenty-five years, the approaches that consider innovation processes can be categorized into five generations of thinking (Rothwell, 1992). The first generation of innovation process was the research-push during the 1950s and 1960s, focusing on the challenge of investing more resources in R&D to produce more products. The second generation of innovation process was demand-pull during the mid-1960s and early 1970s, focusing on the challenge of investment in marketing in order to direct and monitor the R&D activities in line with market demand. Both technology-push and market-pull were too simplistic, leading to a third generation concept of innovation process, which integrated both the research-push and market-pull, regarding innovation as a "logical, sequential, though not necessarily continuous process" (Rothwell and Zegveld, 1985). The management challenge of the third generation of innovation process was to arrange significant investments in cross-organizational communications. The fourth generation of innovation process, developed during the early 1980s to mid-1990s, understood how innovation required, apart from broad inputs from the science base and market, also close relationships with key customers and suppliers. The new (fifth) generation of innovation process includes the growing strategic and technological integration between different organizations inside and outside the companies (Dodgson et al., 2008a).

Innovation rarely occurs through the activities of single companies, but more commonly results from inputs of different stakeholders by interaction and cooperation within a much larger system (Feinson, 2003). Theories on innovation have gradually expanded their focus and complexity, beginning with the individual firm or entrepreneur, moving to a broader view on the environment and industry in which the firm operates, and finally also encompassing the national system of regulations, institutions, human capital and governmental policy (Nelson, 1993, p.210). Furthermore, an increasing number of innovative companies pursue an innovation strategy using external knowledge acquisition strategies, such as cooperation, outsourcing, and licensing-in, in order to benefit from external partners (Batterink, 2009). Companies can compete successfully when they offer new, better, and/or cheaper products and services, which their competitors cannot provide. Innovation projects that aim to develop new, better, and/or cheaper products and services therefore attract the attention of managers that need to reach objectives of higher efficiency and enhanced and sustainable competitiveness (Cooper, 2006; Salomo et al., 2007; Garcia et al., 2008; Salomo et al., 2008). In this study, the management of innovation is studied at the sectoral, company and project levels, which will be further introduced below.

1.2 The importance of innovation for the breeding industry

On the basis of continuous innovations in plant breeding in both public and private sectors, improvements in yield, resistance to biotic stresses, tolerance to abiotic stresses, harvest security, quality improvements including nutritional value, etc., have been established. Improved varieties and high quality seeds have provided great contributions to global agriculture and are a basic requirement for agricultural productivity (Bruins, 2009b). For example, from 1960 to 2011, wheat yields rose by 193%; rice by 136%; maize by 167%; potato by 59%; and vegetables by 105% (FAO, 2013). The increase in yield can be attributed for one half to plant improvements by breeding and for the other half to improvements in agricultural practices, in particular the use of fertilizers, crop protection and irrigation (Silvey, 1978). For some crops, such as cereals, in England and Wales even 90% of the yield increase was realized by the introduction of new varieties (Fischer and Edmeades, 2010). However, the world population is expected to grow from 6 billion in 2012 to 9 billion by 2050, and it has been estimated that crop production needs to be doubled by that time but using fewer resources to achieve this (FAO, 2006). As the agricultural inputs such as arable land, labour, fertilizer, crop protection, and irrigation are getting scarcer or more expensive, a major contribution is expected from a significant improvement in crop productivity. This calls for continuous innovation in the breeding industry.

1.2.1 Vegetable breeding industry in China

China has one of the longest histories of vegetable cultivation in the world. The first Chinese agricultural handbook, Qi Min Yao Su[1], going back to AD 533-544, described the problem of seeds of mixed quality and stated the need to select and keep seeds from the best plants for next year's planting. It also recognized the concept of planting fields especially for seed production considering the fact that most vegetable crops were eaten before seeds matured. Nowadays, there is a wide range of vegetable species and varieties cultivated in China. As explained in Chapter 2, more than 22 million ha was planted in China in 2009, with a production of over 500 million tons, which accounted for 42% of the world's harvested area and 52% of the world's production. However, the average yield in China is still about 35% lower than the average yield of Western Europe and Northern America (FAO, 2012).

The Chinese seed market, in size second after that of the USA (ISF, 2012), is fast growing but also experiencing a radical reform from a planned to a market economy. This industry was highly fragmented with 8,700 seed companies at the end of 2010 (MoA, 2010). Government regulations reduced it to less than 6,500 in March 2013 (MoA, 2013), by raising thresholds to obtain a seed company license. Most of the seed companies are seed producers, processors, or trading companies, which do not invest in breeding. It was estimated that the number of seed companies active in vegetable breeding (VBCs) was only 112 in China in 2012. This is less than 2% of the total number of seed companies in China (Liu et al., 2012c). Those VBCs can be divided into three groups: 1) public VBCs, which are the so-called state-owned companies, often stemming from vegetable research institutes; 2) domestic private VBCs; and 3) foreign private VBCs, including wholly foreign owned subsidiaries and joint ventures. The public VBCs dominated vegetable breeding in China for decades, as most of them were affiliated to public research institutes or offices, which were founded during 1950-1978 and represented the initial Chinese breeding and seed production. The domestic private VBCs stepped into this market especially since 2001, when the enforcement of the new Seed Law in China created the

[1]Literal translation: *Main techniques for the welfare of the people.* It is the most completely preserved of the ancient Chinese agricultural texts, and was written by the Northern Wei Dynasty official Jia Sixie. The text of the book records 1,500-year-old Chinese agronomy, horticulture, afforestation, sericulture, animal husbandry, veterinary medicine, breeding, brewing, cooking, storage, as well as remedies for barren land.

legal opportunity for private capital to enter this industry. Meanwhile, all the global big VBCs are active in China, bringing a lot of competition and challenges to the Chinese vegetable breeding market. The tremendous foreign competition and huge changes during the transition phase make this industry an interesting case for the study of the drivers and barriers that affect innovation and business development.

1.2.2 Vegetable breeding industry in the Netherlands

The Netherlands has become the largest exporter in the world of starting materials of plants (e.g. seeds, cuttings, plantlets for ornamentals, potatoes, and flower bulbs). Companies with their basis and/or main R&D premises in the Netherlands account for about one third of the world's vegetable seed exports and one eighth of the world's vegetable seed imports (ISF, 2011b). This makes the Netherlands both the largest exporting and importing country of vegetable seeds in the world. Worldwide, the vegetable breeding industry has become more and more consolidated due to many mergers and acquisitions over the past three decades. This has resulted in a top ten of vegetable breeding companies that account for over 85% of the vegetable seed market in the world (LEI, 2012). Most of these top ten companies originate from or have important R&D facilities in the Netherlands.

This outstanding position of the vegetable breeding industry in the Netherlands is based on continuous innovation and high R&D investments by VBCs in the Netherlands. Most of these VBCs, founded about one and a half century ago, have developed and consolidated into a few modern high-tech companies with high R&D investments. For example, these VBCs spent on average 19% of the turnover on R&D, which is much higher than the average of R&D intensity (3.3%) across all industries, e.g. pharmaceutical (18%), biotech (11%), electronics and electrical equipment (2%-5%), automobiles and parts (2%-5%), food and beverages (1%-2%), oil and gas (less than 1%) (Cooke, 2006; European Commission., 2012). It is, therefore, of particular interest to uncover the underlying factors that have made VBCs in the Netherlands so outstanding, and the most innovative ones in their field. Evaluating the most important success factors might be beneficial to other countries, such as China, and other industrial sectors.

1.3 Theoretical background of innovation from the knowledge-based view

Knowledge is the most important engine of production (Marshall, 1925), and this is especially true in the knowledge-based economy, which greatly depends on knowledge, information and high-level skills. There is an increasing need for ready access to all of these by both the public and private sectors (OECD, 1996). Investments in knowledge by the OECD countries were estimated to account for 9% of GDP and investments in knowledge including spending on R&D and on software, and public expenditure on education are increasing faster than GDP growth. Economic improvement is largely a result of innovation – the application of knowledge in productivities and the associated adjustments in social institutions (Juma and Yee-Cheong, 2005).

The resource-based view of the company evolved with the claim that competitive advantage derives from resources and capabilities in a company's control that are valuable, rare, imperfectly imitable, and not substitutable (Barney, 1991). It includes both tangible resources such as physical and financial assets, and intangible resources, such as human capital, and reputation (Grant, 1991). These resources and capabilities can be viewed as bundles of tangible and intangible assets, including a company's management skills, its organizational processes and routines, and the information and knowledge it controls (Barney et al., 2001).

Originating from the resource-based view, the knowledge-based view of a company, the most recent development in company theory, views a company as a knowledge-creating entity. Knowledge is the basis for its core competencies, especially the capability of innovation from investment in knowledge management. This view argues that knowledge is the most important source of a company's sustainable competitive advantage (e.g. in terms of low costs, better quality, faster delivery, innovativeness) (Nonaka et al., 2000), because knowledge is usually the most difficult factor to imitate and requires integration across a broad base of capacities (Spender, 1996). Through its knowledge base, a company is able to create new products/processes/services, or improve the existing ones more efficiently and/or effectively (Nelson, 1991; Spender, 1996; Grant, 1997; Teece et al., 1997; Nickerson and Zenger, 2004; Castro et al., 2011). The knowledge-based view can be a useful framework to describe effective routines for a company's innovations.

The knowledge-based view states that innovation is the translation of knowledge into products and processes (Liao et al., 2010). Innovation generation has increasingly been recognized as the outcome of interactions between a company and various outside entities (Roy et al., 2004) and knowledge integration is a fundamental resource for successful innovation (De Luca and Atuahene-Gima, 2007). Understanding the sources of innovation is one of the important elements of management of innovation, and a key challenge faced by new product development projects is how to acquire knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the project or the resulting product (Cooper, 2003). Factors that affect knowledge used for innovation could originate in the knowledge of the recipient, such as a company's existing knowledge and ability to absorb new knowledge (Cohen and Levinthal, 1990) and to adapt previous knowledge and capabilities, e.g. "reinvention" (Rice and Rogers, 1980), as well as a company's strategy to make use of internal and external relationship channels from which they can gain knowledge (Rogers, 1979; Moreland and Myaskovsky, 2000; Batterink, 2009). Therefore, we extend the knowledge-based view by laying further emphasis on the ability to absorb knowledge and on the network needed to access knowledge for innovation of both macro-and micro-innovations at the sectoral, company and project levels.

1.3.1 Innovation at the sectoral level

Managing innovations requires an understanding of the broad sectoral context in which it occurs and of the nature of the innovation process (Dodgson et al., 2008a). Innovation is not only based on the creativity of an individual entrepreneur, researcher, company or research institute, but rather the result of interaction and co-operation within a much larger system (Feinson, 2003). The innovation system approach has been widely used to analyse this broader context, based on the premise that understanding the linkages among the different actors involved in innovation processes, and focusing on the importance of socially embedded knowledge and learning, is key to understanding innovation performance.

The innovation system approach has been used to analyse several innovation systems. It has received most analytical attention as a method for analysing a country's national innovation system (NIS). These analyses were initiated by Freeman (1987), who found that innovativeness not only depends on how the individual institutions perform in isolation, but also on how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal framework). Arnold and Bell (2001) have developed a framework for NIS that is simple and integrative, including all NIS actors, such as companies, universities, research institutes, and technology transfer agencies (Schoser, 1999). This model also takes institutional aspects into account, which are defined by new institutional economics, such as trust levels, standards, norms, rules or laws, etc., and also a typology of all actors within an innovation system (Edquist, 1997; North, 1997). In addition, when regional innovation systems were studied, it was found that geographical proximity and institutional norms and behaviours that have been built over time stimulate knowledge diffusion and integration, which could lead to cluster competitive advantages (Porter, 1990; Freeman, 1995; Malmberg and Maskell, 2002; Braczyk et al., 2004). Apart from national and regional, also sectoral innovation systems were studied, as the national and regional innovation systems rely on the entire ecology of different actors in a country or region, while institutions and forms of organising within an industry or sector are often reproduced with only minor adaptations across a range of countries and regions (Malerba, 2002; Adeoti and Olubamiwa, 2009; Bas and Kunc, 2009). The technological innovation perspective has developed in parallel with the geographic and sectoral perspectives, but emphasizes the specific technologies of the constituting parts of national and international industrial innovation systems (Chaturvedi, 2005; Dodgson et al., 2008a; Dodgson et al., 2008b). These innovation systems enable companies to understand their position within, or integrate themselves in, these systems so as to benefit from their membership (Dodgson et al., 2008a).

The sectoral innovation system (SIS) was defined by (Malerba, 2002) as a set of new and established products for specific uses and a set of agents carrying out market and non-market interactions for the creation, production and sale of these products. Such an SIS approach considers innovation as a collective and interactive process involving various actors. It emphasizes the interactions between institutions and organizations in the private and public sectors (companies, research and education organizations, and intermediaries). These interactions contribute to the development, application, commercialization and diffusion of new technologies and products. Malerba (2002) summarized four different research traditions in studying SIS, focusing on: (i) change and transformation in a particular sector; (ii) links, interdependencies and sectoral boundaries; (iii) interactive processes among a wide variety of actors; (iv) dynamics, processes, transformations and cognitive dimensions affected by previous learning and experiences.

Malerba (2002) found that knowledge and learning is the key determinant of innovation, and Cohen and Levinthal (1990) also indicated that the interaction between a company’s own and external knowledge stocks is important for innovation performance. In this study we further develop the framework borrowed from Arnold and Bell (2001) with an emphasis on analysing the knowledge flow between different actors and the institutional aspects that affect knowledge stocks and knowledge flow. Based on the framework developed by Arnold and Bell (2001), five principal domains that constitute an SIS were identified: 1) the business domain, with a focus on companies that apply and use codified knowledge and produce mainly tacit knowledge; 2) the research & education domain, with a focus on the professional and higher education and research institutes that produce and transfer codified knowledge; 3) the intermediate organizations that stimulate knowledge transfer and application; 4) the market demand referring to the final demand from consumers and the intermediate demand from other actors in the production chain; and 5) the infrastructure and framework conditions that include the more general aspects that can influence innovation, such as finance, taxation, and mobility.

The SIS approach was to study innovation in the vegetable breeding industries both in China and the Netherlands. The vegetable breeding industry in the developing economy of China is extensive, has experienced large changes in the last decade and still is in the middle of a turbulent economic reform. The vegetable breeding industry in the Netherlands is part of a well-established economy and is based on a highly innovative industry with over one century of development. These large differences between two countries make it worthwhile to analyse the SIS of the vegetable breeding industry in China and the Netherlands, based on the same theoretical framework. This approach will give us an insight into the similarities and differences between a well-developed and a developing SIS.

Research Question 1 (RQ1): what are the main drivers and barriers for an effective and well-functioning sectoral innovation system in the cases of China (Chapter 2) and the Netherlands (Chapter 3)?

1.3.2 Innovation at the company and project level

The business domain plays an important role in a SIS, as this is where the innovation takes place and the new products are being developed. So, in Chapter 4 and Chapter 5, the study focus shifts to the company and project levels to explore the key success factors and mechanisms that affect innovation and business performance. In this part of the study, the focus will be on the important role of knowledge at the company and project levels, since companies are social communities/organizations that specialize in creation, integration and the internal transfer of knowledge (Kogut and Zander, 1992). Knowledge is considered the most strategically important asset of a company, as it is usually difficult to imitate, and, therefore, regarded as the major determinant of sustained competitive advantage and superior company performance (Blindenbach-Driessen and van den Ende, 2006).

According to the knowledge-based view, a company's success depends on how well it can 1) enhance its own knowledge base by either creating or obtaining new knowledge, 2) integrate its different knowledge areas, and 3) apply its knowledge to the development or enhancement of products or processes (Kogut and Zander, 1992; Spender, 1996; Blindenbach-Driessen and van den Ende, 2006). As innovation in VBCs is mostly initiated, organized and executed in the form of R&D projects for the development of new crop varieties or breeding processes, factors that affect the innovation process at the project level were examined as well.

Previous studies suggest that innovation may considerably benefit from being embedded in networks in order to gain access to potential outside knowledge (Audretsch and Feldman, 1996; Feldman and Audretsch, 1999; Fritsch and Slavtchev, 2007; Fritsch and Kauffeld-Monz, 2010). Innovation networks are critical for a company's innovation performance (Camagni, 1991), because networks constitute a valuable resource that all partners within the network can use. They can tap into specific social structures, in which their companies are embedded, to pursue their interests (Baker, 1990; Nahapiet and Ghoshal, 1998). Empirical studies have revealed that innovation networks have a positive effect on innovation by enabling access to potential outside knowledge, coupling innovation resources, breaking through technical barriers, stimulating technological improvements, and reducing innovation risks (Freeman, 1980; Freeman et al., 1991; Haythornthwaite, 1996; Sternberg, 2000; Rodan and Galunic, 2004; Freel and de Jong, 2009).

Innovation is also dependent on the company's absorptive capacity. Proposed initially by Cohen and Levinthal (1990), and further defined by Pavitt (2002) and Daghfous (2004), absorptive capacity is the ability of a company to recognize the value of new, external information, assimilate it, and apply it to commercial ends (Pavitt, 2002; Daghfous, 2004). Absorptive capacity is important because knowledge that is not freely available, or for sale, is often of a tacit nature (i.e. not codified) and highly context-specific, so companies have to acquire certain capabilities to be able to absorb this knowledge (Sternberg, 2000; Lööf and Heshmati, 2002; Reagans and McEvily, 2003; Lazaric et al., 2008; Schmidt, 2010).

Based on the work of Kogut and Zander (1992), Lane and Lubatkin(1998), Van Den Bosch (1999), Zahra and George (2002), and Camisón and Forés(2010), it was established that absorptive capacity has four dimensions: acquisition, assimilation, transformation and application. 1) acquisition capacity is a company's ability to locate, identify, value and acquire indispensable external knowledge that is critical to its operation; 2) assimilation capacity is a company's ability to absorb external knowledge; 3) transformation capacity is a company's capacity to develop and refine the internal routines that facilitate the transformation and combination of previous knowledge with the newly acquired or assimilated knowledge; and 4) application capacity is a company's ability to build the acquired, assimilated and transformed knowledge into its operation routines and create new operations, goods and organizational forms. These four dimensions are divided into two components: potential absorptive capacity (acquisition and assimilation), and realized absorptive capacity (transformation and application). Organizations that possess relevant prior knowledge are likely to have a better understanding of new technology, and can generate new ideas and develop new products more efficiently. It results from a prolonged process of investment and knowledge accumulation (Tsai, 2001).

Various factors that influence the level of absorptive capacity have been described in previous studies, and can be categorized into three groups: R&D activities, related prior knowledge and individual skills, organizational structure and human resources (Schmidt, 2010). Cohen and Levinthal (1990) focused mainly on the role of R&D expenditures in building absorptive capacity and pointed to the dual role R&D plays in the innovation process of companies: building absorptive capacity and generating new knowledge and innovations. Many other researchers used R&D-related measures such as R&D intensity (R&D expenditure/total sales) and continuous R&D activities (Cantner and Pyka, 1998; Rocha, 1999; Stock et al., 2001). However, Flor and Oltra (2004) found that direct information, e.g. self-assessment by managers, is more effective in identifying both product and process innovators. R&D investments constitute a necessary, although not sufficient, condition for a company's absorptive capacity (Caloghirou et al., 2004a), absorptive capacity tends to develop cumulatively and builds on prior related knowledge (Cohen and Levinthal, 1990). As companies' absorptive capacity depends heavily on the quality of their employees, the general level of education, experience and training has a positive influence on a company's level of absorptive capacity. However, a company's absorptive capacity is not just the sum of its employees' capabilities (Cohen and Levinthal, 1990), it also depends on the ability of the organization as a whole to stimulate and organize the knowledge transfer across departments, functions and individuals (Schmidt, 2010). Cross-functional communication can improve absorptive capacity if it leads to better knowledge-sharing among functional units and individuals within a company. Moreover, the organizational culture can have a positive influence on the level of absorptive capacity if it provides incentives for knowledge diffusion through the empowerment of employees (Daghfous, 2004).

Businesses invest heavily in R&D, because it may increase the acquisition and understanding of scientific and technological knowledge for further use in the development of new products/processes and improvement of current products/processes, which in turn would grant them important competitive advantages. In 2009, the American business sector spent $282 billion on R&D, accounting for 71% of the total US R&D expenditure bill (Agrawal and Henderson, 2009). Innovation is highly encouraged in companies and supported by heavy R&D investments, especially in the breeding industry in the Netherlands (Dons and Bino, 2008).

There are many factors related to the success of innovation projects, such as functional capabilities, communication, teamwork, resources, etc., although the interaction mechanisms among these different factors in the innovation project are still not clear. Tepic (2012) explained that there are two types of capabilities often referred to, and considered important in the context of innovation. One type includes the functional capabilities that are related to deepened and adequate functional knowledge, in terms of technology, manufacturing, marketing, distribution, sales and financing, etc., and the other type consists of the integrative capabilities, referring to communication, team interaction, and knowledge sharing (Grant, 1991; Dutta et al., 1999; Nath et al., 2010; Kim et al., 2011; Fortune and Mitchell, 2012). However, the interaction between functional capabilities and integrative capabilities and how this interaction affects innovation project performance is still not clear.

As described above, innovation may considerably benefit if a company is embedded in networks that help them to get access to potential ineluctable outside knowledge. It is also dependent on absorptive capacity, the capacity to absorb and implement outside knowledge and apply it to commercial products. The studies in Chapter 4 and 5, based on empirical data from VBCs both in China and the Netherlands, address the effect of the innovation network and absorptive capacity on innovation and business performance.

Research Question 2 (RQ2): what is the role of the innovation network and the absorptive capacity for a company's innovation and business performance at the company (Chapter 4) and project (Chapter 5) levels.

1.4 Thesis setup

This thesis consists of six chapters, which can be arranged into three parts, including: introduction of innovation at sectoral, company and project levels, empirical studies at these three levels, and the final discussion and conclusion. Figure 1.1 presents an overview of the whole book.

Chapter 2 and Chapter 3 analyse the innovation systems of China and the Netherlands at the sectoral level using the SIS framework. The main actors in the sector, such as companies, research institutes, education organizations, government agencies, intermediate agencies, and the interaction mechanisms among actors, market demand and institutions that affect knowledge flow are placed in the SIS framework.

Chapter 4 presents the effects of innovation network and absorptive capacity on innovation and business performance at the company level, based on empirical data collected from VBCs in China.

Chapter 5 presents interrelated factors affecting innovation at the project level, from a perspective of absorptive capacity, and based on the empirical data collected from project leaders of innovation projects of VBCs in China and the Netherlands.

Chapter 6 provides a synthesis of the four empirical studies on innovation at sector, company, and project level. It gives answers to the research questions about improving innovation at different levels, and highlights the theoretical contributions and managerial implications of this research, as well as indicating its limitations and giving some directions for further research.

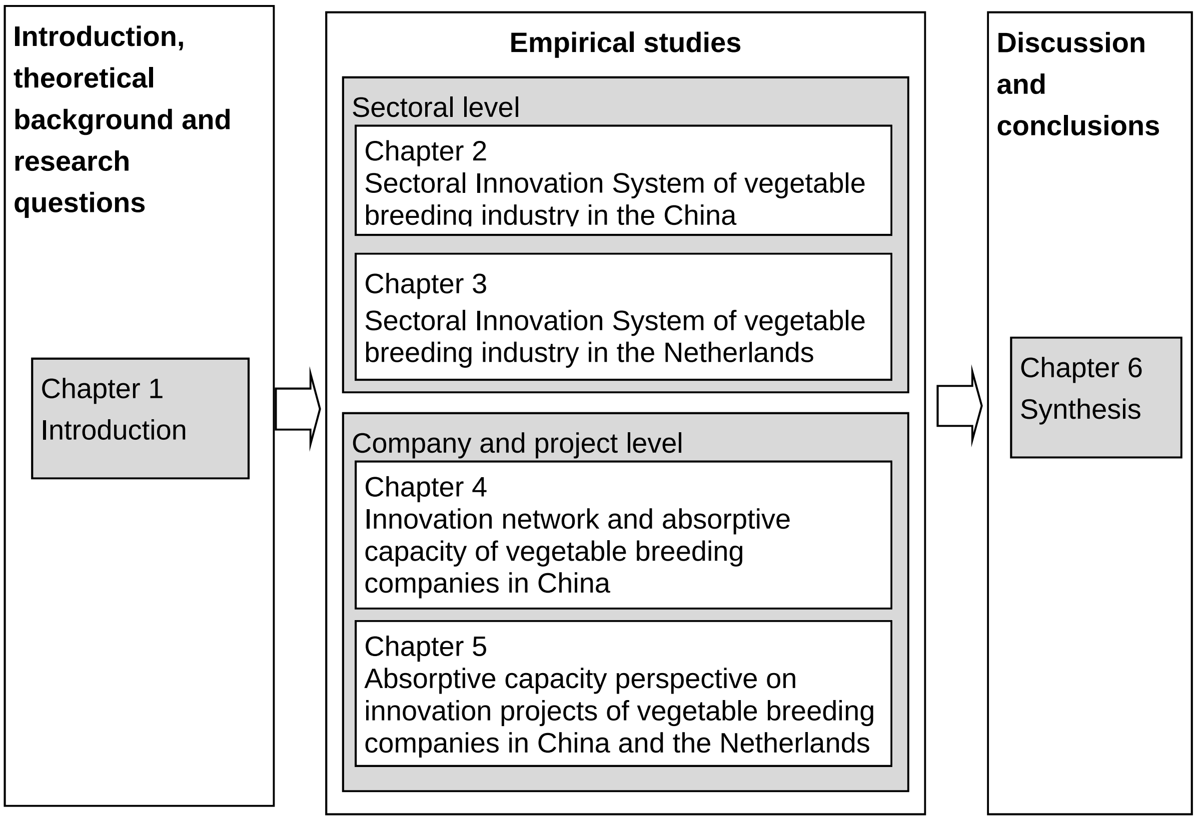

Figure 1.1 The outline of this book

2. The sectoral innovation system of the vegetable breeding industry in China[2]

2.1 Introduction

The plant breeding industry plays important roles in the public domains related to food, agriculture, trade and the environment (Louwaars, 2007). It has to meet the challenges in food production and consumption by developing new varieties with high yield, resistance to biotic stresses, tolerance to abiotic stresses and better quality. This is especially true for the vegetable breeding industry in a country like China, which accounts for nearly half of the world's vegetable production and consumption (FAO, 2012). Currently, a rapid transition from a planned to a market economy is happening in China, and the breeding industry is under heavy pressure from foreign companies that are technologically advanced. It is interesting, therefore, to study the sectoral innovation system of the vegetable breeding industry in China to identify the drivers of and barriers to innovation, to come up with recommendations of actions that can be taken to cope with these changes.

The Chinese national seed system was initiated in the 1950s shortly after the founding of the People's Republic of China. During the period 1950-1978, the Chinese Academy of Agricultural Science (CAAS) and many local, public vegetable research institutes or offices were founded all over the country. These institutes represented the initial Chinese vegetable breeding and seed production system. Then, after the introduction of the reforms and opening-up policies in 1978, the national seed system (all crops) was further developed and consisted of approximately 3,000 state-owned seed companies in 2000 (Huang et al., 2001a), which were responsible for seed production and distribution. The vegetable breeding industry is still dominated by the public vegetable research institutes, but they were encouraged to set up seed businesses to commercialize their technological achievements since the 1980s.

In 2001, the enforcement of the new Seed Law in China created the legal opportunity for private capital to enter this industry. As a result, the number of seed companies soared to

[2] This chapter is based on Zhen Liu, Maarten A. Jongsma, Caicheng Huang, Deyi Zhou, J.J.M. (Hans) Donsa and S.W.F (Onno) Omta. The sectoral innovation system of the Chinese vegetable breeding industry, submitted to China Agricultural Economic Review.

over 8,700 in 2010. Recently, in April 2011, the State Council released a formal document "Guiding Opinions on Accelerating the Development of the Modern Crop Seed Industry" (referred to as "Guiding Opinions"), and based on this, in September 2011, the Ministry of Agriculture (MoA) enforced a directive "Administrative Measures on the License of Seed Production and Operation", by which the entry-threshold such as registration capital was significantly increased.

Innovations are not the result of creativity of an individual company/research institute or entrepreneur/researcher, but are situated within a large system (Feinson, 2003). Previous studies of innovation in the seed industry were either about seed policies (Pal and Tripp, 2002; Rohrbach et al., 2003; Louwaars, 2007; Lal, 2008) or the seed business (Schimmelpfennig et al., 2004; Kamphuis, 2005; Kumar and Ali, 2010) both in developing and developed countries. However, there has been no systematic analysis of the relationships and interactions among multiple players. In this study, an integrated framework – called Sectoral Innovation System (SIS) – is applied to systematically study the vegetable breeding industry in China.

This chapter is organized as follows. In Section 2.2, the theoretical framework of SIS is introduced. In Section 2.3, the methods of data collection and analysis are described. Then in Section 2.4, the results from different domains of the SIS of the vegetable breeding industry in China are presented, and in the final Section 2.5, an integrated picture of the SIS of this industry that explains the role of innovation networks in the performance of this industry is presented and discussed.

2.2 Theoretical framework

The National Innovation System (NIS) is one of the approaches to study innovation, which is based on the premise that understanding the linkages among the actors is the key to understanding innovative performance (Freeman, 1987; Lundvall, 1992; Nelson, 1993). From this perspective, the innovative performance of an economy depends not only on the performance of individual companies, research institutes, and universities, but also on the interactions with each other (Smith et al., 1996). The NIS framework of Arnold and Bell (2001) is simple and integrative, with both the narrow NIS actors such as companies, universities, research institutes, technology transfer agencies and technology policies (Schoser, 1999), and broad NIS institutional aspects, such as trust, standards, norms, rules or laws, etc., and also the actors within an innovation system (Edquist, 1997; North, 1997). It has been used to analyse the national (Feinson, 2003; Balzat and Hanusch, 2004; Lee and Park, 2006), regional (Chen and Guan, 2011), sectoral (Malerba, 2002; Gilsing, 2005; Adeoti and Olubamiwa, 2009; Bas and Kunc, 2009), and technological determinants of innovation (Chaturvedi, 2005; Dodgson et al., 2008b).

Here the focus is on the sectoral innovation system (SIS) of the vegetable breeding industry in China. There are four research traditions in studying SIS: (i) emphasis on change and transformation in sectors; (ii) examination of links, interdependencies and sectoral boundaries; (iii) focus on an interactive process among a wide variety of actors; (iv) use of a broad theoretical framework and evolutionary theory, with emphasis on the dynamics, process, transformation and cognitive dimensions that are affected by previous learning and experience in the environment (Malerba, 2002).

Considering the importance of interaction between proprietary and external knowledge stocks to the performance of SIS (Cohen and Levinthal (1990) and accepting the statement by Malerba (2002) that knowledge and learning is the key determinant of innovation, the fourth SIS approach was applied to analyse the vegetable breeding industry in China. The vegetable breeding industry in China was evaluated within the framework of the flow of knowledge among the five principal domains specified by Arnold and Bell (2001): 1) the business domain, 2) the research & education domain, 3) the intermediate organizations, 4) the market demand, and 5) the infrastructure & framework conditions (Figure 2.1). The business domain, research & education domain and intermediate organizations are the main stakeholders in the industry. The knowledge stock generated within and the knowledge flow among the business domain, research & education domain and intermediate organizations determines the innovation and development of the seed industry, while market demand and infrastructure & framework conditions further modify this process.

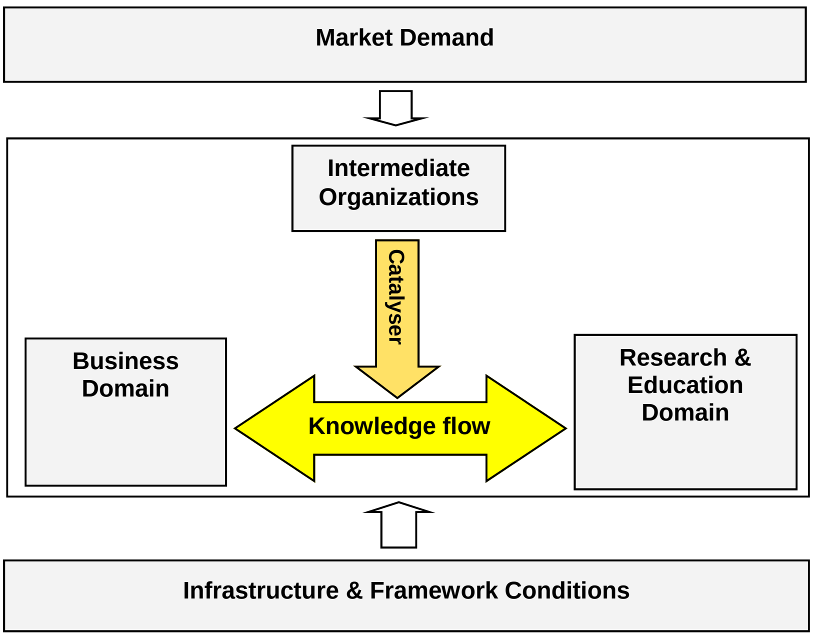

Figure 2.1 Framework of Sectoral Innovation System

2.3 Research methods

Among the 8,700 seed companies in China at the end of 2010, most were seed production, processing, or trading companies. In the present study, the focus was on breeding companies that are genuinely active in innovation, implying they should have R&D in breeding. By that criterion, only a small percentage of these 8,700 seed companies were breeding companies. According to the official list (www.seed.gov.cn) in December 2010 and based on three criteria: active in breeding, seed production and sales; focus on vegetables; and having more than 10 employees, we identified 112 vegetable breeding companies (hereafter referred to as VBCs). This selection was verified and where needed corrected by several interviewed vegetable seed business experts. The VBCs could be divided into three types: a) 49 public companies, which were state-owned companies and vegetable research institutes that were also involved in the breeding business; b) 50 domestic private companies; c) 13 foreign private companies. 70 VBCs were visited that were located in ten provinces and three municipalities (Beijing, Shanghai and Tianjin), representing the major locations for VBCs and the primary regions of vegetable production in China in 2010 and 2011 (Figure 2.2).

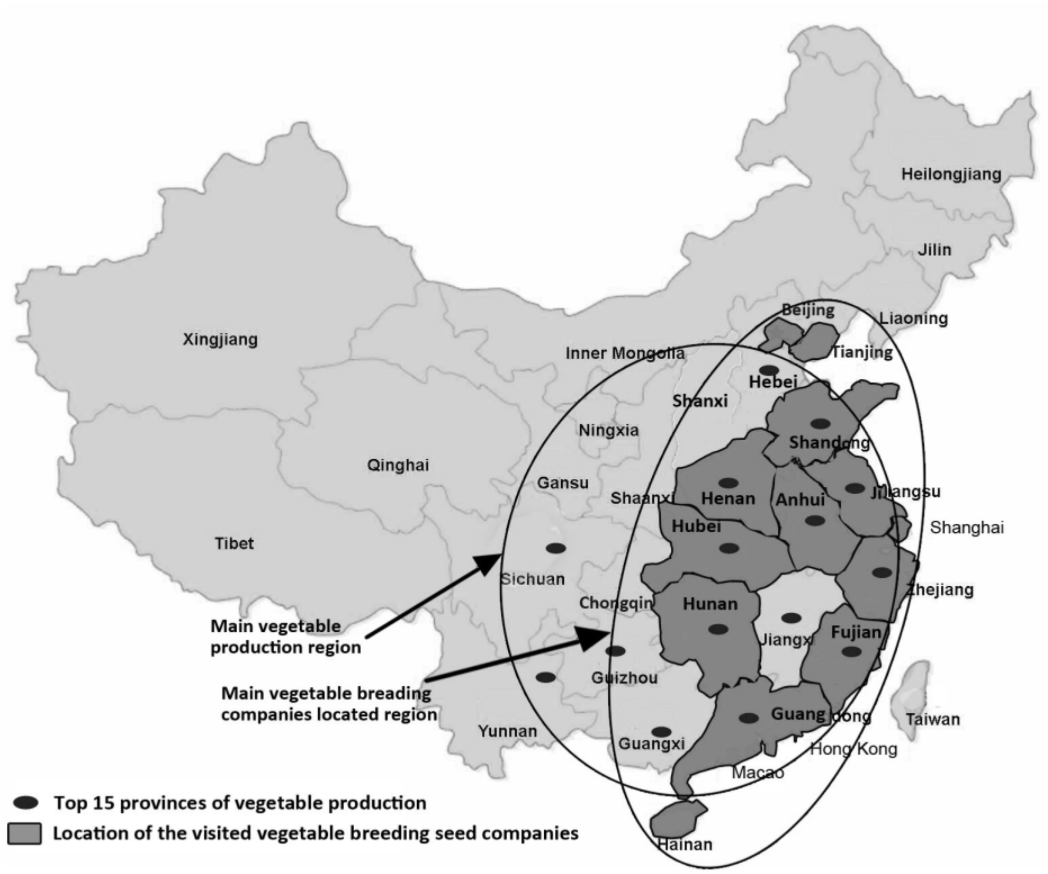

Figure 2.2 Distribution of vegetable breeding companies in China

In each of the visited VBCs, one or two senior managers were interviewed. The following six aspects were discussed: 1) history and current organization of the company, 2) business environment, 3) innovation strategy and input, 4) company and personal network, 5) absorptive capacity, and 6) innovation and business performance. Furthermore, other experts from research institutes, government agencies and intermediate organizations were interviewed, to gain additional information from these stakeholders in the vegetable breeding industry. Furthermore, archival data, such as series of statistical yearbooks from both domestic and international sources and series of regulations and governmental documents about the breeding industry were checked and summarized. The assembled information for each of the five domains of SIS is presented separately in the following results section. Then, an integrated picture and evaluation of the SIS of the vegetable breeding industry in China is described.

2.4 Results

2.4.1 Business domain

In China in 2010, it was distinguished 49 public, 50 private and 13 foreign VBCs. Each of these categories operates from very different contexts and is analysed separately after which the findings are compared. The business domain of public, domestic private and foreign VBCs was analysed separately and the findings were then compared.

Public VBCs

Public VBCs have been in a leading and monopoly position for a long time. They can be subdivided into two types: state-owned and institute-owned.

The first state-owned seed company was the China National Seed Group Corporation founded in 1978 and this example of state-ownership was replicated at lower governance levels. As a result, at the end of the last century there were 2,700 state-owned companies at the national (1), provincial (30), municipal (500) and prefectural (2200) level (Huang et al., 2001a). All of them mainly focused on seed production and distribution of varieties obtained from research institutes at no or low costs. In December 2000 only 5% of them were profitable, about 70% insolvent, and 20% bankrupt (Tong, 2010). This serious situation called for a strong reform, and led to the enforcement of the China Seed Law in 2000 (Huang et al., 2001a), allowing privatization, and resulting in much fewer state-owned companies (<30 now) mainly at the national and provincial level (Tong, 2010). Those remaining companies focus mainly on field crops, and thus are not very influential in the innovation of the vegetable seed industry. For this reason, they are not further included in the analysis.

Institute-owned breeding companies have started to operate since the middle of the 1980s, when policy makers began encouraging research institutes to earn extra income through commercial activities. As a result, today, these institutes have developed over 60% of the current vegetable varieties, which are commercialized mainly by themselves or licenced exclusively to their affiliated seed companies. However, such commercial activities did not lead to the expected improved breeding research or technology transfer (Huang et al., 2002). It was even claimed to have potentially hampered innovation in the breeding industry, because of the unfair competition it presented to private VBCs (Tong, 2010). The policy to overcome this problem was stimulating research institutes to separate commercial activities from their public research tasks (Huang and Hu, 2004). In 2011 this was emphasized again in a new policy document "Guiding Opinions" (2011). To this date the separation of public and commercial activities has not been completed, and as a result, institute-owned VBCs can still be further divided into three groups based on the degree of separation between commercial activities and public research: integrated, intermediate and separated institute-owned VBCs. Their similarities and differences are presented in Table 2.1.

Table 2.1 Comparison of integrated, intermediate and separated institute-owned breeding companies

Items / Type	Financially independent from research institute	Personnel independent from research institute	Use of varieties developed in research institute	Examples
Integrated	No	No	Exclusive	VRI of Zhejiang AAS[1]
Intermediate	Partly	Partly	Exclusive/with priority	Tianjin Kernel Cucumber Research Institute (TKCRI)
Separated	Yes	Yes	Without priority	VRI of Jiangsu AAS

[1] VRI-Vegetable Research Institute, AAS- Academy of Agricultural Sciences

Domestic private VBCs

Domestic private breeding companies are the largest group, growing extremely fast since 2001. They were founded and developed in the following four ways:

- Starting from scratch. Some private VBCs originated from small seed retailers in the late 1980s, when the field crops seed market was monopolized by state-owned companies, while the vegetable seed market was not regulated that much. Some of those pioneers developed successfully and started to invest in breeding new cultivars.

- Founded by agricultural researchers. In the middle of the 1980s when the agricultural reform policies encouraged research institutes to commercialize their products, many entrepreneurial researchers left their institutes to start their own seed business (Huang et al., 2002). This was relatively easy as the intellectual property of the institutes and universities was not protected by law until 1997.

- Founded by company employees. Due to the reform and privatization, many employees in the state-owned seed companies either left and started their own seed company or bought one of the bankrupt state-owned seed companies. Most of them were turned into seed production and sale companies, and only a few became true VBCs.

- Supported by capital investment. The quick growth and strong support by favourable government policies in the breeding industry attracted a lot of interest from other industries. They either stepped in and founded VBCs or extended their portfolios (e.g. fertilizers, pesticides, vegetable production, etc.) to include the seed business. These companies grew quickly by buying varieties from research institutes, or sponsoring independent breeders (such as retired researchers, farmer breeders, etc.) to get exclusive rights on competitive varieties for the market.

Foreign VBCs

The large and rapidly growing market and economic reform in China also attracted foreign VBCs. They entered the Chinese market by either exporting seeds to China or setting up subsidiaries and/or joint ventures (JVs). However, the regulations governing R&D and commercial activities of foreign VBCs in China have become increasingly restrictive over the past 15 years and can be divided into laws given prior to 1997, from 1997-2007, and after 2007, according to Catalogues for the Guidance of Foreign Investment Industries) (Ma and Bo, 2007). Foreign VBCs starting businesses before 1997 were allowed to establish a wholly foreign owned enterprise (WFOE), in breeding as well as seed production and sales in China. Those starting in 1997-2006, could still create a WFOE for R&D in breeding, but had to establish a JV, holding a minority share, for seed production or sales, while since 2007, foreign VBCs have to establish JVs for all activities (Table 2.2).

This complex situation has led to a variety of strategies of foreign VBCs in China. Some invest heavily in breeding and produce and sell seeds in China, while others choose to only export their seeds to China via agents, in consideration of the restrictive laws and weak intellectual property protection.

Table 2.2 Accessibility of the Chinese vegetable seed market for foreign investors in different periods

Seeds business in China[1]			
	Breeding	Seed Production	Seed Sales
Foreign companies founded in China before 1997	Open to WFOE[2]		
Foreign companies in China founded in 1997-2006	Open to WFOE	Only open to JVs[3]	
Foreign companies founded in China since 2007	Only open to JVs		
Seeds imported to China			
Seed companies abroad	Through seed companies with import and export license (domestic companies or JVs in China)		

[1]anything deviating from this table should refer to the official regulations: summarised from Catalogue for the Guidance of Foreign Investment Industries version 1997, 2003 and 2007.
[2]WFOE, wholly foreign owned enterprise, in which a foreign company holds 100% shares
[3]JVs, joint ventures, in which domestic partner(s) hold a majority share

Comparative assessment of the three types of VBCs

Table 2.3 shows the baseline description of the 51 VBCs in China, The VBCs are characterized as small-sized in terms of the number of employees and the turnover, 75% of the VBCs has less than 60 employees and a turnover of less than 30 million RMB (approximately 3 million euros). The VBCs invest intensively in R&D (14.2% of turnover) and in R&D human resources (R&D personnel accounts for 1/3 of the total personnel of the VBCs). However, it needs to be noticed that the public VBCs, especially the research institutes that are active in the seed business, received a large amount of R&D subsidies from the Chinese government. The cultivars sold by public VBCs all stem from the research institutes they are affiliated to; that explains why the percentage of R&D compared to the turnover could go up to 60% of the turnover.

The size of public and domestic private VBCs is similar both in number of employees and turnover, but much smaller than the foreign ones, especially taking into account that they only represent 1-10% of their mother company. The R&D budget of public and foreign VBCs is at the same level (18% of turnover), and nearly double that of the private ones. But it should be noted that the public VBCs gain substantial governmental funding, while the foreign VBCs are strongly supported by their mother companies. Table 2.4 summarizes the main research activities in the various VBCs. The top three activities are breeding, germplasm collection and seed technology. In general, the public VBCs are more active in all activities while the private ones focus much more on practical breeding, e.g. germplasm collection. Compared to the public and domestic private VBCs, the foreign companies seem to be less active in most research activities, due to the strong support from their mother companies.

Table 2.3 Basic information of three types of vegetable breeding companies in China

	Min.	Max.	Mean	S.D	Mean Public(26)	Private(32)	Foreign(12)
Number of employees	12	167	44	33	40	41	74
Turnover 2010 (million RMB)	1	90	23	22	20	20	69
Number of R&D employees	2	80	15	16	19	9	28
R&D budget (% of turnover)	2	60	13	11	18	10	18
Age of company (years)	3	52	15	9	15	14	16

[a] This high percentage is due to the public VBCs that are affiliated to the research institutes, which receive large amounts of R&D subsidies and are functioning as R&D department of the public VBCs.
[b] The age of R&D department is higher than the age of the oldest company. This is due to the fact that the vegetable research institutes were founded much earlier than their affiliated seed companies (public VBCs), which use the former as R&D functional unit.

Table 2.4 Research activities of these three types of vegetable breeding companies

Research activities	Public[1]	Private	Foreign	Total
Breeding	100%[2]	100%	100%	100%
Germplasm collection	83%	93%	38%	81%
Seed technology (e.g. quality control, seed coating)	61%	74%	38%	64%
Basic research (e.g. new breeding methods)	67%	22%	13%	36%
Plant tissue culture(e.g. DH production)	50%	22%	25%	32%
Use of molecular markers	44%	22%	13%	28%
Phytopathology research	39%	15%	13%	23%
Use of genetic modification (GMO)	11%	4%	13%	8%
Genomics and bioinformatics	6%	0%	13%	4%

[1] Public-public breeding companies; Private-domestic private breeding companies; Foreign-foreign private seed companies.
[2] % = percentage of companies in each type that conduct a certain research activity

2.4.2 Research & education domain

Agricultural research

After the rapid expansion in the past half century, China now has one of the most comprehensive agricultural research systems in the world. Agricultural research (AR) is mainly financed by the public sector under responsibility of several agencies at the national, provincial and prefectural levels (Zhang and Kempenaar, 2009). There are 1237 AR institutes in total. National, provincial and prefectural institutes account for 12 %, 51% and 34 % of the total AR budget respectively (Huang et al., 2003).

The total AR personnel was reduced substantially from 1991 to 2000, and then remained stable at around 100,000 while R&D personnel grew gradually (Figure 2.3). This was due to large numbers of researchers leaving during the period of transition from a planned to a more market-oriented economy (Huang and Hu, 2004). Since 2000, government funding for AR has increased substantially, leading to more R&D employees, while self-raised funds by enterprises (the enterprises affiliated to these public research institutes) decreased considerably (Figure 2.4). As a result China ranks 5th for public AR staff per million people among the developing countries. However, the average public agricultural R&D investment per researcher is still one of the lowest (ASTI, 2010). Furthermore, the private investment in AR, with 27% average growth during 2000-2006, is growing faster than the 14% annual increase of public investments in AR institutes. However, private investment, usually the major source of innovation and productivity growth, is limited as it accounts for only 17% of total agricultural R&D, which is much lower than that in OECD countries (over 50%) (Hu et al., 2011).

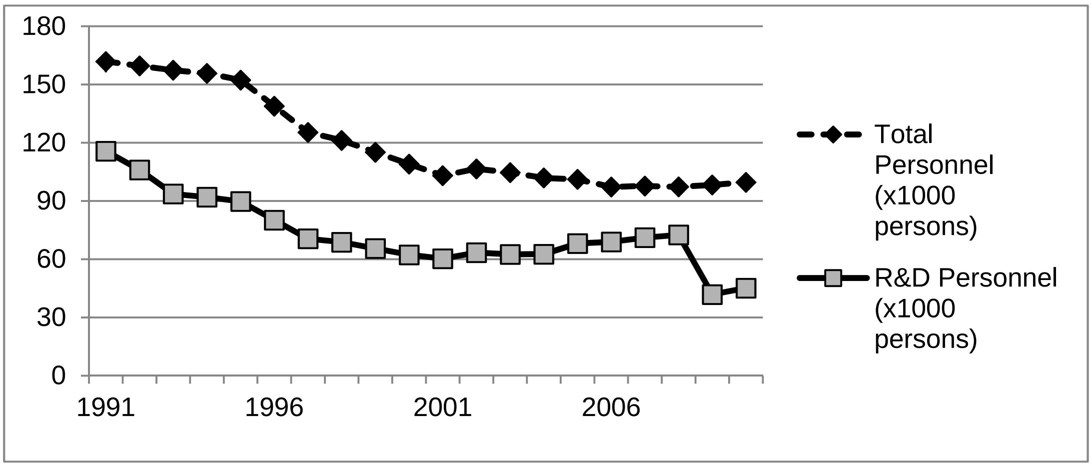

Figure 2.3 Number of personnel in agricultural R&D Institutes in China 1991-2010
Source: Data extracted from The China Statistical Yearbook on Science and Technology from 1992 to 2011
Note: The statistic was changed since 2008 by excluding the supportive staff for R&D, which was included before 2008

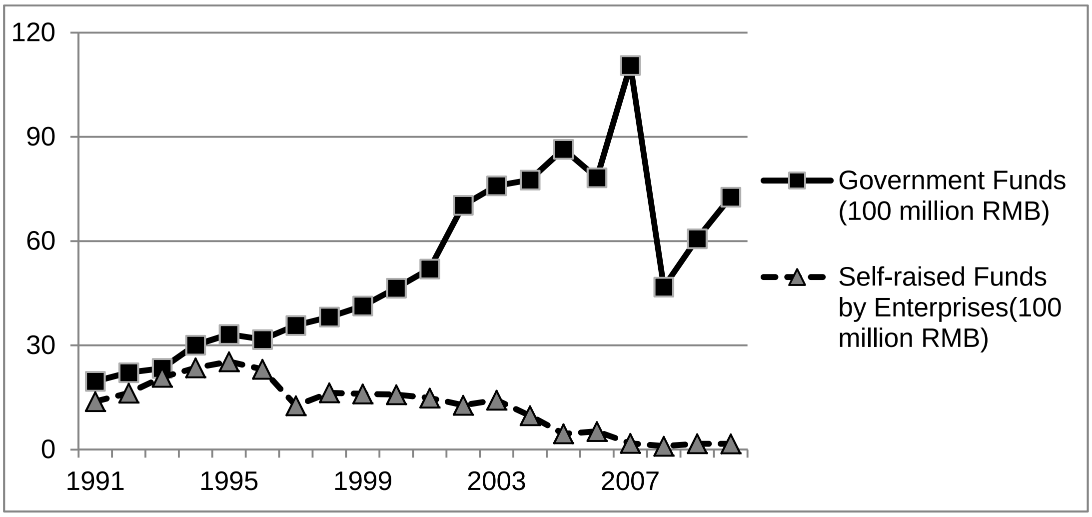

Figure 2.4 Source of funding for S&T Activities in agricultural R&D Institutes, 1991-2010
Source: Data extracted from The China Statistical Yearbook on Science and Technology from 1992 to 2011
Note: The statistic was changed since 2008 by excluding the supportive staff for R&D, which was included before 2008. So the huge drop of number of researchers in 2008 is because the different statistical caliber, in general, it still shows a trend of increase.

In vegetables, there were over 5,500 employees in 119 vegetable research institutes and about 930 vegetable researchers in 38 less specialized AR institutes in 2010 (Agridata, 2012) (Table 2.5). Due to decentralised organization, there are only 20-92 researchers per institute working on many disciplines such as genetics, breeding and other agricultural subjects. Among them, plant biotechnology has been one of the most important aspects since the 1980s.

Table 2.5 Institute number and staff size in the public vegetable research system in China 2010

Vegetable research institutes				
	National	Provincial	Prefecture	Total
No. of institutes	3	22	94	119
No. of personnel	275	1370	3937	5582
No. of R&D personnel	206	760	2034	3000
No. of personnel/ institute	92	62	42	47
%. of R&D personnel	75%	55%	52%	54%
Other agricultural research institutes with vegetable research				
	National	Provincial	Prefecture	Total
No. of institutes	N.A.	5	33	38
No. of personnel of vegetable department		285	645	930
No. of R&D personnel of vegetable		193	412	605
No. of personnel/ institute of vegetable		57	20	24
%. of R&D personnel		68%	64%	65%

Source: Data exacted and summarized by authors from http://www.agridata.cn

Plant biotechnology was considered by China's government to be one of the primary means to improve its national food security, raise agricultural productivity and secure its competitive position in international agricultural markets (Huang and Hu, 2004). Hence investment in agricultural biotechnology has increased much faster (about 30%) than investment in agricultural research (about 14%) (Huang and Hu, 2004). This growth has been sustained as the State Council approved a special science and technology fund of about US $3.5 billion for research on biotech crops from 2006-2020 (Lagos and Wu, 2011). As a consequence, the number of plant biotechnology researchers has more than tripled in the last two decades, in contrast to the declining trend of public AR staff (Figure 2.3).

The perception is that the increasing investment in plant biotechnology has paid off. A successful example is the development and widespread adoption of insect-resistant *Bt*-Cotton, developed by CAAS. Another example is the high number of patent applications filed related to plant biotechnology (6030 in 2009). Two thirds of those were from domestic applicants, and 89% of domestic applications were from universities and research institutes. However, it should be noted that only 15% of all domestic applications are still valid, compared to 79% of foreign applications, which is perhaps due to over-stimulation to file applications and a lack of encouragement to maintain them. The Chinese investments and participation in the Human Genome Project has enabled Chinese researchers to achieve positions at the forefront of genomics, further promoting plant biotechnology. For example, the Beijing Genomics Institute (BGI) has grown to be one of the largest genomics centres in the world, with more than 4,000 employees. They participated in the genome sequencing of many important crops such as potato and cucumber in 2011 and tomato in 2012, which will certainly benefit agricultural (biotechnology) research and plant breeding.

Agricultural education

According to the Ministry of Education in 2009, China had the largest agricultural education system in the world, with 88 agricultural colleges and universities, attended by 380,000 bachelor, 35,000 master, and 9,600 PhD students, and with 34,000 teachers. However, the number of agricultural students per 1,000 inhabitants is only 0.3, which is three times less than that in the Netherlands (0.9) (Holwerda and Voskuil, 2011). Moreover, the large majority of them move to other disciplines after graduation. For example, five years after graduation, only one out of 80 bachelor students of horticulture, who graduated in 2004 from Huazhong Agricultural University (one of the top five agricultural universities in China) was still working in the same industry. This may be due to the lesser attractiveness of agriculture in general, and the poor match between the graduates' skills and VBCs' needs.

2.4.3 Intermediate organizations

Public extension network

By the mid-1980s, a comprehensive extension network was established in agriculture with one million employees in the mid-1990s. Because of over-staffing and inefficiency, the total personnel were reduced by one quarter in the period until 2006 in a series of reforms (Figure 2.5). On the other hand, investments have grown strongly, with an average annual increase of 26%, which is much higher than the AR annual budget increase (14%), showing a higher priority given to improving extension.

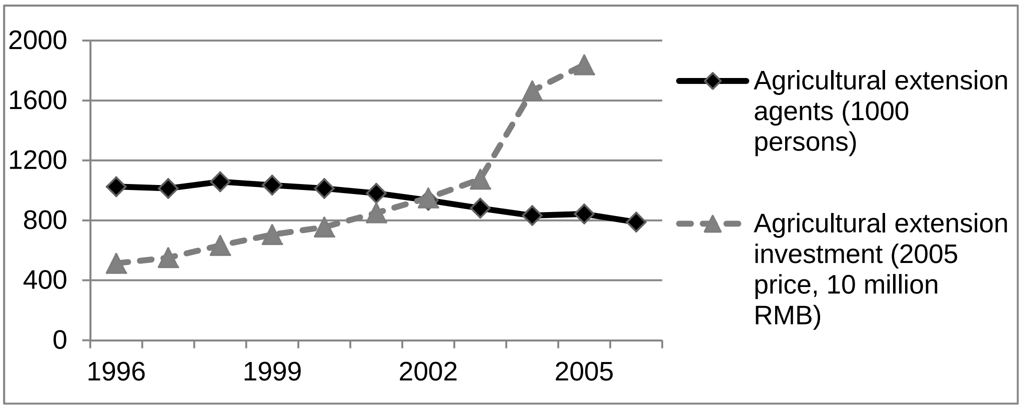

Figure 2.5 Agricultural extension investments and number of agricultural extension personnel from1996 through 2006
Source: China Statistical Yearbook on Science and Technology (1991-2006)

Seed associations

The China National Seed Association (CNSA) and the China National Seed Trade Association (CNSTA) are the two main nation-wide seed associations. CNSA, founded in 1980 and located at the MoA, acts as an extension agent of MoA to improve the administration of the seed business. CNSTA, founded in 1988 and located at the China National Seed Group Corporation, is the official representative of China in international meetings and societies such as the International Seed Federation (ISF). The major members of these associations are state-owned companies and domestic private companies, including those involved in seed production and sales (Liu and Zhang, 2009). Apart from these two, there are also provincial and prefectural seed associations, administrated by CNSA, in most provinces and some cities. Of the 70 VBCs were interviewed, about half were members of CNSA, and over 80% were members of the local provincial or/and prefectural seed associations. Although they were highly motivated to join associations for the purpose of networking and obtaining market and policy information, they were dissatisfied with the results, because the associations exerted only limited influence on government policy making and were not effective in facilitating cooperative activities among breeding companies.

Seed exhibitions

Four well-known exhibitions held every year in Beijing, Shouguang, Wuhan and Guangzhou, are dedicated to vegetable seeds. They act as brokers to link business and research. Based on the authors' experience in the last five years, most foreign companies were very well represented in these exhibitions, and some of them always acted as main sponsors. Meanwhile, the participation of domestic private companies was increasing, and of public companies was decreasing, in line with the observed changes in the seed business. Most of the interviewed VBCs found the exhibitions an effective way to present their products and company, establish contacts with their distributors, get to know their competitors and be informed of the latest regulations.

2.4.4 Market demand

China had the world's largest growing area (42%), production (49%) and consumption of vegetables (48%) (FAO, 2012). The harvested area and production has grown steadily in China and the rest of the world in the last three decades (Figure 2.6), and may further grow due to the increase in the world's population. However, despite the fact that the average yield of vegetables (in tonnes per ha) in China is slightly higher than the world's average, it is still much lower than that in Western Europe and North America, and the gap did not significantly decrease over the last two decades (1990-2010) (Figure 2.7). Moreover, the vegetable seed commodity rate (percentage of commercial seed over total seed) is only 40% in China, while it is over 90% in developed countries (Zhang, 2011), which implies that there is a large potential market for better-quality vegetable seeds.

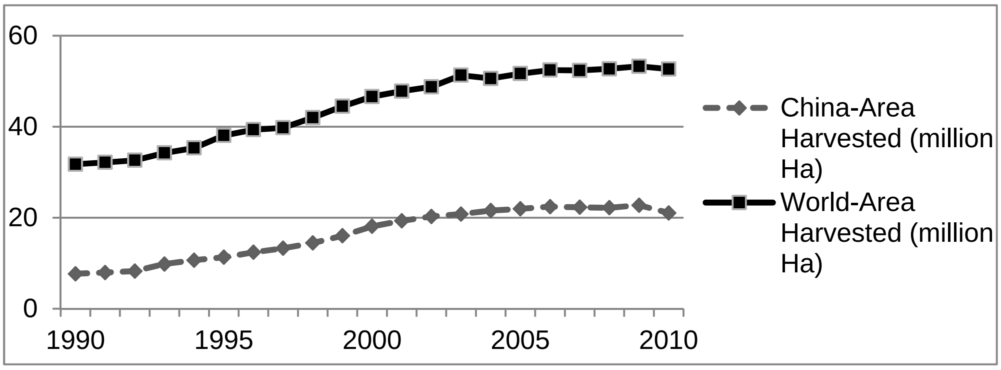

Figure 2.6 Vegetable harvested area and production in China and worldwide from 1989 through 2009
Source: http://www.fao.org

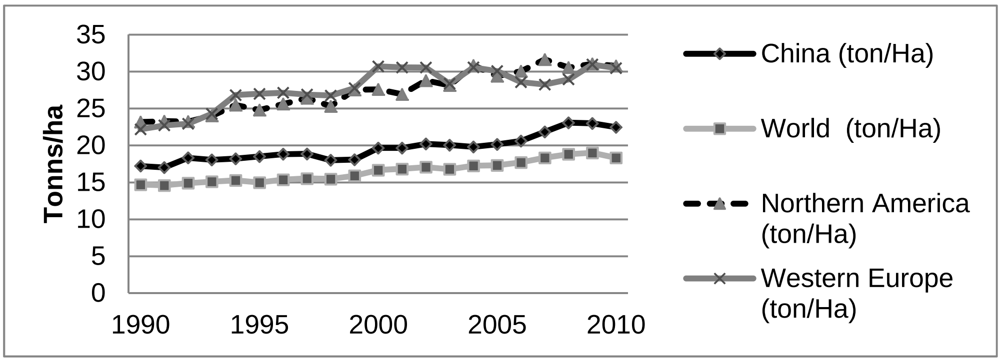

Figure 2.7 Comparison of the average vegetable yield in China with other parts of the world from 1989 through 2009
Source: http://www.fao.org

This demand for better seeds is stimulated by the fact that although the average size of a vegetable farm is still very small (0.2 ha) (Van den Berg et al., 2007), more and more larger specialized vegetable farmers, such as in Shouguang region, are coming up and demanding high-quality seeds as they realize the benefit, despite the higher seed prices. As a result, the share of foreign seeds already accounts for 60-70% of the seed market in Shouguang. It is reasonable to expect that this development towards a more efficient, high-yielding agriculture in Shouguang will spread to the rest of China (Zhang, 2011). When taking the vegetable supply chain into account, there are many additional opportunities for VBCs. For example, year-round demand for supplies that need to be transported over long distances created a strong demand for long-shelf-life characteristics, and resulted in many varieties with such traits (Yang, 2005). Moreover, in the transition from a quantitatively insufficient supply to a demand-driven situation, higher quality and diversity in terms of colour, shape, fragrance, taste and health-promoting aspects of vegetables are new selling points for VBCs.

2.4.5 Infrastructure and framework conditions

Germplasm resources and accessibility

The Chinese Crop Germplasm Resource Information System (CGRIS), established in 1986, is a central repository for all types of plant genetic resources in China, housing 390,000 accessions of 180 crops species. It consists of six sub-systems: 1) the management system of the National Crop Gene Bank (NCGB), 2) the management system of the long-term storage in Qinghai, 3) the management system of the National Germplasm Resources Nursery (NGRN), 4) a database of crop characterization and evaluation, 5) a database of national and international germplasm exchange, and 6) the management system of National Medium-term Storage (NMS) in Beijing. Regarding vegetables, there are about 28,000 accessions in the NMS in Beijing and another 1,500 accessions of (water)melons in the NMS in Henan (ICGR, 2011).

The NBGB is the long-term conservation centre for national strategic crop genetic resources in China. Access by any organization or individual requires permission from the MoA. Access to the listed germplasm kept in NGRN and NMS for research and/or breeding purposes is free of charge or at low cost for domestic users, but restricted for foreign VBCs and JVs, which need to obtain a special permit from MoA six months in advance.

As indicated by CGRIS, the number of applications for vegetable germplasm is around 1,000 per year. Most applicants, however, are research institutes and not domestic or foreign companies. The interviews revealed that although most of them knew CGRIS well, they very rarely made use of the resources, because the application procedure was too complex, and there were too many restrictions on their use, especially for foreign VBCs. The public VBCs that did obtain germplasm from CGRIS also had concerns about the usefulness of the material.

Plant variety protection in China

China enforced a Plant Variety Protection (PVP) Act in 1997 and became a member of the International Union for the Protection of New Varieties of Plants (UPOV) on April 23, 1999 (1978 ACT). Since then, until the end of 2011, there were 7,753 applications and 3,708 of those were granted PVPs for all crops. For vegetables, there have been 453 applications and 131 granted PVPs , accounting for about 5% of the total applications and grants (MoA, 2012). The majority of applications are public VBCs, but their share decreased strongly from 75% in 2006-2008 to 49% in 2009-2011, though the number of applications still increased. By contrast, the percentage of applications from private domestic VBCs increased from 10% to 29 % in 2009-2011 (Figure 2.8a). This reveals that private VBCs are realizing the importance of protecting their innovations, and are becoming active in breeding, gradually assuming a role in the innovation of the vegetable breeding industry. In more detail, Figure 2.8b shows the number of applications of the top 10 vegetable crops in 2000-2011.

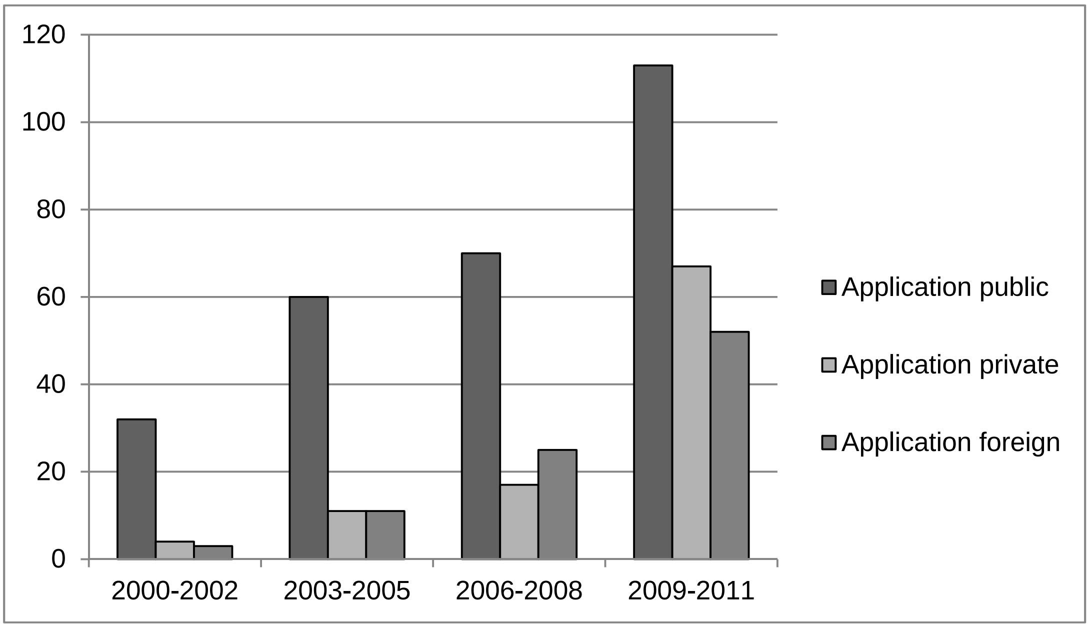

Figure 2.8a Number of applications for PVP on new vegetable varieties from 2000 through 2011
Source: The office for the Protection of New Varieties of Plants, MoA, P.R. China

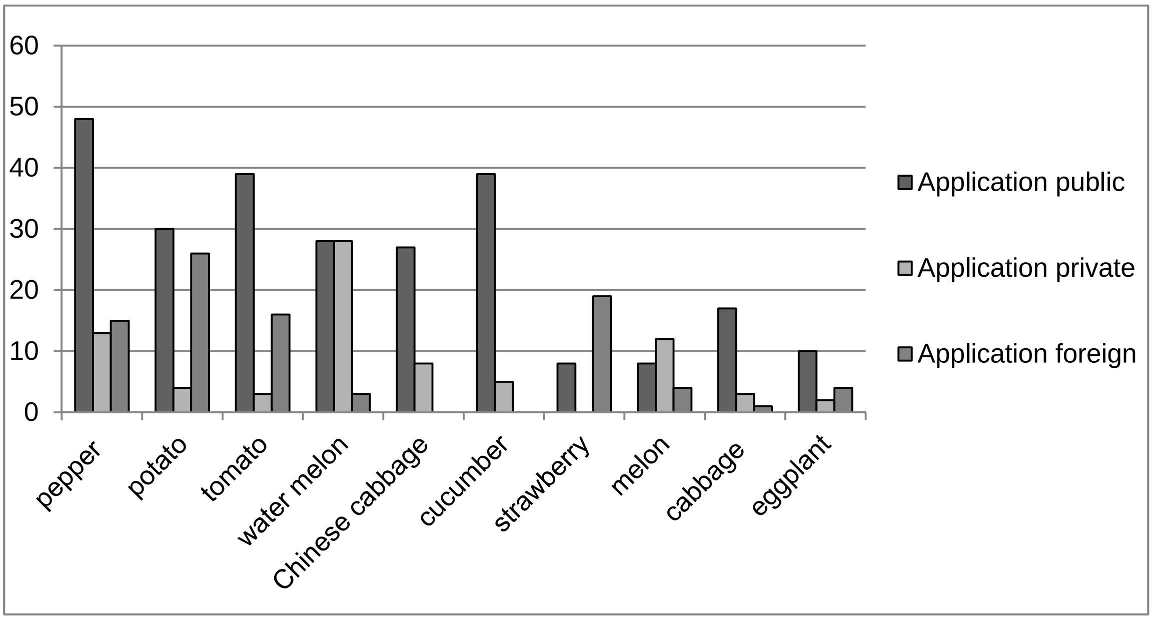

Figure 2.8b Number of applications for PVP among different vegetables from 2000 through 2011
Source: The office for the Protection of New Varieties of Plants, MoA, P.R. China

Plant variety registration

Plant variety registration is independent of plant variety protection in China and is mandatory for several staple crops such as rice, wheat, corn, cotton, and soybean, which are classified as major crops at the national level. In addition, each provincial agricultural administrative department may select two others as major crops for which new varieties must be registered before market release. These may include specific vegetables at the provincial level, such as Chinese cabbage in Shandong and hot pepper in Hunan province. Since the introduction of the regulation of plant variety registration, 886 (water)melon, 212 Chinese cabbage, 181 potato, 90 cucumber, 86 tomato and 60 pepper varieties have been registered, which is much more than the number of applications for PVP (Figure 2.8b). The reason for that appears to be that companies can sell registered varieties without PVP. This is preferred because applications for PVP do not give adequate protection, and are costly and time consuming. In addition, two further issues were extracted from the interviews. Firstly, the two methods used internationally to approve new cultivars are not yet fully implemented. Those are the DUS test (distinctness, uniformity and stability) to prove it is new, and the VCU test (Value for Cultivation and Use) to show it is useful in terms of growth and yield. Especially the DUS test is not yet fully developed or standardized. This results in many duplicated applications which are not detected by the system according to Teng et al (2009), and the Department for Protection of New Varieties of Plants of MoA (interview). Just very recently, The State Council made the decision to modify the Regulations on the Protection of New Varieties of Plants by adding the requirement of the DUS test (State Council, 2013).

Secondly, the assessors and applicants may have overlapping interests, because the assessment committees are made up of representatives of agricultural administrative departments, research institutes and universities, while the majority of applicants are from public VBCs, which are affiliated to these institutions. In the interviews this was said to lead to inadequate examination of the registered cultivars. Some private VBCs stated explicitly that they don't apply for cultivar registration, because the assessors might be their potential competitors, and as a result "*most registered vegetable cultivars are not on the market, and most marketed ones are not registered*". As a consequence, distrust of both registered and non-registered varieties is commonly shared by farmers, and crop failures are often blamed on seed quality, as experienced by most interviewed companies. To achieve a healthy seed business in China, improved procedures for variety registration, therefore, appear necessary (Teng et al., 2009).

Seed policy

The Enterprise Income Tax Law and Implementation Rules of the People's Republic of China stipulate that income generated from newly bred varieties shall be exempted from enterprise income tax. This favourable policy might enhance the development of the breeding industry. However, it is only applied for the seed companies with license of operating through a combination of production and research, nursing and multiplication and owning breeding capability. This policy is almost impossible for all VBCs, because this license requires minimal register capital of 10 million CNY, which is too high for VBCs.

The "Guiding Opinions" (2011) released by the State Council aimed at further strengthening the seed industry and stimulating innovation in breeding (Table 2.6). Its goal for 2020 is to boost breeding capacity and coverage with elite varieties to ensure a steady supply of grains and other major agriculture products. As an implementation of the "Guiding Opinion", the "Administrative Measures on the License of Seed Production and Operation" encouraged consolidation in the seed industry by increasing the entry threshold of new companies (Lagos and Lei, 2011b). For example, the minimal registered capital for vegetable seed companies was initially recommended to be increased from 1 to 5 million RMB, though it was only doubled in practice for an operational license. The reason for lowering the planned threshold was that over 80% of the vegetable seed companies could not meet the criteria. On the other hand, there is no minimum registered capital requirement for seed production licenses, but the producer needs to obtain an official license from the owner of plant varieties if the produced seeds carry plant breeders' rights. This reveals a trend to stimulate innovation in this industry by strengthening PVP.

Table 2.6 Summary of the "Guiding Opinion on Suggestions for Accelerating the Development of Modern Crop Seed Industry"

5 Goals by 2020	• To establish new multidisciplinary, highly efficient breeding systems with improved resources • To breed a set of breakthrough proprietary varieties • To build a group of standardized, large-scale, specialized and mechanized seed production bases • To create several modern seed industry groups characterized by high breeding capacities, advanced production and processing technologies, excellent marketing networks and well-placed technical services • To improve seed management system, with clear responsibilities, advanced tools and an effective regulatory framework
4 Basic Principles	• Independent innovation • Enterprise-oriented • Trinity of enterprises, universities and research institutes • Supporting the superior and strong enterprises
9 Key tasks	• Strengthen fundamental agricultural research in the seed industry • Enhance talent cultivation in the seed industry • Establish commercial breeding systems • Promote mergers and acquisitions among seed enterprises • Enhance seed production base construction • Perfect the seed reserve regulation and control system • Implement strict variety registration and protection • Consolidate market supervision and administration • Enhance international cooperation and communication of the seed industry
11 Strategic actions	• Work out a modern crop seed industry development plan • Increase business investments in large breeding companies • Implement a new set of programs related to the seed industry • Establish a mechanism of innovation evaluation and technology transfer • Encourage the flow of scientific and technological expertise to the industry • Implement the seed business tax incentive policy • Improve seed production, purchasing and storage policies • Refine seed-related laws and regulations • Establish a sound seed management system • Leverage the role of industry associations • Strengthen coordination and leadership across ministries

Source: State Council of the People's Republic of China, translated and summarized by author.

2.4.6 Integrated picture of the sectoral innovation system of the vegetable breeding industry in China

An integrated picture of the vegetable breeding industry in China is presented in the framework of SIS, with specific elements/stakeholders and some main characteristics of each domain (Figure 2.9). The most important finding of this study is that the knowledge flow is limited. There are two main reasons for this. On the one hand, investment in innovation by VBCs is suppressed due to the weak intellectual property protection, which ensures that they may benefit from innovation, while they can also rely on developments initiated by research institutes. One the other hand, public organizations such as public VBCs, research institutes, universities, extension agents, etc. are simultaneously active in all three domains, resulting in limited internal and external collaboration incentives.

Within the business domain, the breeding industry is fragmented, with many small companies with low investment capacities, and there is unfair competition between private and public VBCs, because public VBCs gain substantial subsidy for R&D. The role of public VBCs is weakening, however, due to the policies that encourage them to separate commercial activities from public research. Furthermore, their small size and ambiguous ownership structures make them inefficient and not very competitive (Tong, 2010). By contrast, the private companies are starting to invest more in R&D, and are becoming competitive relative to the public companies. Despite the strong constraints imposed on foreign companies, they are expected to remain very active and competitive in the vegetable breeding industry in China.

Within the research & education domain, the public agriculture R&D investment in the last three decades has been increased about 8% annually, which is more than anywhere else in the world (Pardey et al., 2006). However, private investment, usually the major source of innovation and productivity growth, is limited as it accounts for only 17% of total agricultural R&D, which is much lower than that in OECD countries (over 50%) (Hu et al., 2011). Furthermore, all vegetable research institutes are organized in small units, based on crops. This fragmented, duplicated organization structure is not efficient, especially in the light of the large investments and collaborations that are necessary to work with complex modern breeding technologies.

Within the intermediate organizations domain, there has been a substantial increase in public investments in the agricultural extension system. However, the current intermediate organizations are too close to the government, and there is a very limited number of PPP, especially on R&D. For example, in the new vegetable subprogram of the "Modern Agricultural Industry Technology System" (MoA, 2007), created to bridge the gap between research and application, participation of private industry was rarely encountered during the interviews.

The strong and sustained growth of the Chinese seed market and the potential for increasing the seed commodity rate from 40% to 90% lead to large opportunities for VBCs in the near future. The policy environment currently aims to encourage innovation and development in the breeding industry by introducing legislation which for example reduces fragmentation of the breeding industry. Since the enforcement of these regulations in 2011 this has already led to a reduction of the number of seed companies in two years by more than one quarter. Overall, the continuous emphasis on agriculture by the State Council over the past 12 years will be continued in the coming 12th five-year program of the Chinese government since 2001 (Lagos and Lei, 2011a), due to the recognition of its importance in food security. The government recognizes the importance of the breeding industry and issues legislation to improve the situation. However, the conflict between the PVP and plant variety registration is still a generally recognized problem in this industry and restrictions on foreign investment in this industry would limit the knowledge flow from abroad into China.

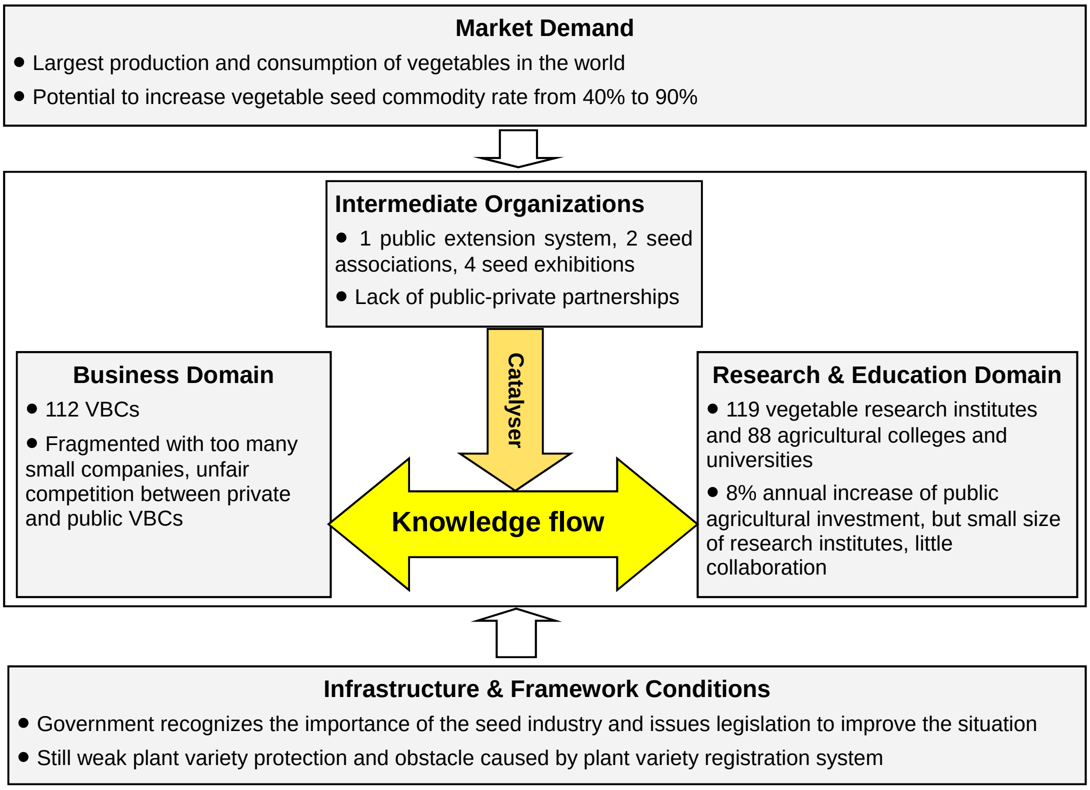

Figure 2.9 Integrated picture of the relationships within the sectoral innovation system (SIS) of the vegetable breeding industry in China

2.5 Conclusions and policy implications

Based on the SIS of the vegetable breeding industry in China, it can conclude that the VBCs in China have not yet achieved positions as the driving forces for innovation. First of all, the VBCs are a very small group within the whole vegetable seed industry, 112 VBCs compared to 4,000 vegetable seed companies (half of all the seed companies in China are involved in the vegetable seed business). Secondly, the weak intellectual property protection in China leads the VBCs to limit their investment in innovation. Furthermore, the VBCs still rely on the varieties of the public research institutes, which were the dominant force of innovation in the seed industry for decades. Moreover, due to their small size and the lack of cooperation among VBCs, it is very difficult for VBCs to make use of modern breeding technologies that require heavy investments and accumulated knowledge. The central role that breeding companies should play in innovation in the seed industry has been recognized by the Chinese government.

Frustrating this desirable path of development is the dominant role of the government in almost all domains of the SIS of the vegetable breeding industry in China, with public VBCs in the business domain, with heavy public investments in the research & education domain, and with government-instituted intermediate organizations. Their incentives for collaboration are limited, a situation which constrains the knowledge flow especially towards the business domain. The multiple roles performed by the government lead to conflicts of interest with the private companies, which create obstacles for policy enforcement and the evolution of a healthy vegetable seed industry. Publicly funded R&D investments, especially the applied R&D, discourage private R&D investments, because breeding companies can rely on licencing varieties developed by public research institutes rather than develop varieties themselves. Moreover, publicly funded R&D investments in the vegetable breeding industry in China are not efficient, as the research institutes are fragmented into small units, based on crops and provinces, which do not allow for the economic volume that is needed to use modern breeding technologies.

Innovation of VBCs should be strengthened in order to stimulate the vegetable breeding industry in China. It can propose that the enforcement of the intellectual property protection by implementing the DUS test both for plant variety protection and registration regulation, which would help to protect intellectual property. Consolidation by merging of VBCs and collaboration among VBCs by the foundation of private-public consortia needs to be stimulated, because it would help VBCs to invest in breeding technologies that require economies of scale. Public research institutes should focus on fundamental, strategic and pre-competitive research to create common knowledge for the whole vegetable breeding industry, such as new pre-breeding materials and technologies, and leave commercial activities such as new cultivar breeding, seed production and sales to VBCs. So the further separation of commercial and R&D activities within research institutes should be enforced. Furthermore, the role of the government should concentrate on support rather than on direct action in the context of innovation. Possible new roles for the Chinese government are: supporting the establishment of public-private partnerships, encouraging participation of the VBCs in public research and their involvement in the application of new technologies, stimulating private R&D investments, e.g. with subsidies, and encouraging consolidation and collaboration to increase efficiency in the vegetable seed industry.

3. The sectoral innovation system of the vegetable breeding industry in the Netherlands[3]

3.1 Introduction

After one century of development in the seed business, the Netherlands has become one of the major exporters in the world of plant reproduction material (seeds, cuttings, plantlets for ornamentals, potatoes, flower bulbs, grasses, and vegetable seeds), representing an increasing export value of 2.5 billion euros (Plantum, 2012). Companies in the Netherlands enjoy positions as global market leaders in plant reproduction material. This position is based on craftsmanship, entrepreneurship and innovation, and as a result the breeding industry in the Netherlands is cited as one of the most innovative in the world (LEI, 2012). Particularly in the vegetable breeding industry, companies with their basis and main premises in the Netherlands account for about one third of the world's vegetable seed exports and one eighth of the world's vegetable seed imports (ISF, 2011b). This makes the Netherlands both the largest vegetable seed exporting as well as importing country. Over the past three decades, the vegetable breeding industry has become more and more consolidated due to many mergers and acquisitions. As a result the top ten vegetable breeding companies (VBCs) now account for over 85% of the vegetable seed market in the world (LEI, 2012), and most of these top ten companies originated in the Netherlands or have important R&D facilities in the Netherlands. It is, therefore, of particular interest to uncover the underlying factors that made the seed sector in the Netherlands the most innovative in this field, so that other industrial sectors may benefit from this.

In a number of studies, the vegetable breeding industry in the Netherlands has been described as a highly innovative sector, but the reasons behind this high level of innovation have not yet been analysed systematically (Liu et al., 2004; Kamphuis, 2005; Dons and Bino, 2008; Dons and Louwaars, 2009; Schenkelaars et al., 2011). Generally speaking, the development of new products and processes is not only based on the creativity of individual researchers, entrepreneurs, companies or research institutes, but

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[3] This chapter is based on Zhen Liu, Maarten A. Jongsma, Caicheng Huang, J.J.M. (Hans) Dons and S.W.F (Onno) Omta. The Sectoral Innovation System of the Vegetable breeding industry in the Netherlands, submitted to NJAS - Wageningen Journal of Life Sciences.

rather is the result of interactions and co-operation within a much larger system (Feinson, 2003). In other words, innovation is dependent on the interaction between the proprietary and external knowledge stocks of stakeholders in the system (Cohen and Levinthal, 1990). Connections across companies and industries have been shown to be fundamental to competitiveness, productivity, and especially to the direction and pace of new business formation and innovation (Porter, 2000). Successful innovations require a collective effort bringing together people, ideas and targets that were previously separate, and an effective networking among heterogeneous entities spanning various markets and technologies (Hulsink and Dons, 2008). In this study, the same framework of the Sectoral Innovation System (SIS) was used, which is further developed from the model of Arnold and Bell (2001) and used in Chapter 2, by putting more emphasis on the knowledge flow within the system. The links and interactions among different stakeholders (business, research and education organizations, intermediate organizations, etc.) were analysed systematically to understand how and why the vegetable breeding industry in the Netherlands is outstanding.

This chapter is organized as follows. In Section 3.2, the theoretical framework of SIS is introduced. In Section 3.3, the methods of data collection and analysis are described. Then in Section 3.4, the results from different domains of the SIS of the vegetable breeding industry in the Netherlands are presented, and in the final Section 3.5, an integrated picture of the SIS of this industry that explains the role of innovation networks in the performance of this industry is presented and discussed.

3.2 Theoretical framework

In recent years, the NIS framework has been used to analyze certain countries, such as Norway (Smith et al., 1996), China (Sun and Liu, 2010) and all OECD countries (OECD, 1999). The framework can also be used to analyze a certain type of industries (Sectoral Innovation System, SIS) (Malerba, 2002), such as the cocoa industry (Adeoti and Olubamiwa, 2009) , and the IT industry (Lee and von Tunzelmann, 2005). In other cases, the focus has been on the innovation system surrounding a new technology, such as biotechnology (Kaiser and Prange, 2004; Chaturvedi, 2005; Dodgson et al., 2008b).

In this study, the SIS approach was applied with the same research framework of Figure 2.1 in Chapter 2 to produce an analysis of the vegetable breeding industry in the Netherlands. It is hypothesized that the available stock of knowledge and the knowledge flow generated within and among the first three domains play an important role in the innovation performance of the breeding industry. It is expected that the other two domains, market demand and infrastructure & framework conditions, influence this process. The arrows in Figure 2.1 represent the main flows of knowledge. In the following sections, the five domains of SIS of the vegetable breeding industry in the Netherlands will be analysed in more detail.

3.3 Research methods

To ensure the validity of data collection and analysis, A triangulation approach was used by looking from different angles at the same phenomenon, and by using different data collection strategies and data sources (Pettigrew, 1973; Denzin and Lincoln, 1994; Stake, 1995; Yin, 2003). Different data collection strategies were applied to the business domain, research & education domain, and intermediate organizations domain. Archived data, such as fiscal statistical year books from both domestic and international sources and regulations and governmental documents, were checked and summarized.

In analyzing the business domain, the vegetable seed industry in the Netherlands appeared to be highly consolidated with only 28 companies active in the vegetable seed market. Many of them are only active in producing and selling seeds. Only ten companies could be identified as VBCs that were active in breeding, seed production and sales, and with a reasonable size (> 10 employees). All other companies in this seed industry were either smaller or only active in trading seeds. The VBCs were either private family-owned companies or part of large multinational companies (Table 3.1). These 10 companies were visited and interviewed one or two senior managers for 1-2 hours using a semi-structured interview and asked them to fill in the questionnaire. In the interview as well as in the questionnaire the following six aspects were addressed: 1) history and current organization of the company, 2) business environment, 3) innovation strategy and input, 4) company and personal network, 5) absorptive capacity, and 6) innovation and business performance.

Table 3.1 Overview of vegetable breeding companies in the Netherlands in 2011

	Private family-owned companies	**Part of multinational companies**
[1]Large	• Rijk Zwaan • Enza Zaden • Bejo Zaden	• Monsanto Vegetable Seeds • Syngenta Seeds • Nunhems (Bayer Crop Science) • Nickerson-Zwaan (Vilmorin & Cie) • Takii Europe[3] (Takii Japan)
[2]Small	• Pop Vriend Seeds • Agrisemen	

[1] Large: with more than 1,000 employees; [2]Small: between 11 and 100 employees ; [3] In the analysis, Takii Europe was excluded from the group of multinationals, because of its special structure. It is a European subsidiary of a Japanese family-owned company.

For the research & education domain, I interviewed researchers from the Plant Sciences

Group of Wageningen University and Research Center, which is the most important research partner for the VBCs in the Netherlands. Feedback on the impact of the research & education domain on the vegetable breeding industry, was also collected through the interviews with the senior managers of the 10 companies.

Publications and citation data of scientific publications in plant breeding and plant biotechnology were used to identify the international position of Dutch research in this field. Based on the search profile of Borsi and Schubert (2011), publications and citation data were taken from Thomson–Reuter's Web of Science (WoS) from 1945 onwards. The publications that were relevant to the breeding business were: plant genetics, plant molecular biology, and plant breeding. The top 1% of all publications were extracted based on their citation indices. It was found that the top 1% cited papers had been published between 1990 and 2005. To avoid any bias that might arise from recent publications having generally lower citation rates, the whole period was divided into four segments: 1945 to 1980, 1981 to 2000, 2001 to 2009, and 2010 to 2012. The most cited papers written by authors from research organizations of different countries were identified, assuming that these organizations had closely linked research collaborations. Finally the linkage data was entered into UCINET (Borgatti et al., 2002), a software tool for social network analysis.

In addition I conducted interviews with experts from stakeholders in the intermediate organization domain such as governmental agencies and intermediate organizations, like Naktuinbouw, Plantum, and The Centre for BioSystems Genomics (CBSG), to gain information from all stakeholders on the innovation system of the vegetable breeding industry in the Netherlands.

3.4 Results

3.4.1 Business domain

The business domain of the vegetable breeding industry in the Netherlands comprises 10 VBCs, where most of the innovation takes place and products are developed. The investigation revealed that the business domain of the vegetable breeding industry in the Netherlands is highly consolidated, globalized, innovation-driven and co-evolved with the supply chain.

Historical background, development and consolidation

The commercial production and sale of vegetable seeds in the Netherlands started over

150 years ago with the foundation of Sluis & Groot in 1867 in Andijk, a small village in the province of North Holland. Later on, the firm moved to Enkhuizen after the establishment of the first railway between Enkhuizen and Amsterdam. Nowadays, Enkhuizen is still home to a number of important VBCs, but also in other parts of the Netherlands, concentrations of vegetable seed businesses have developed, for example in the Westland region near Rotterdam and in the southern provinces. The region around Enkhuizen in the province of North Holland is now part of the so-called Seed Valley.

Before the Second World War, development of new cultivars was done by small growers and small pioneer seed trading companies. In those days, the production and sale of seeds and the selection of better cultivars was done within the same company. A growing number of companies entered into the market as the seed business emerged. Figure 2 shows that there was a continuous growth of the number of vegetable seed companies from the 1860s to the 1940s.

Since the Second World War, companies involved in seed selection were transformed into professional plant breeding companies, in which science-based breeding became the core activity. The experiments of Gregor Mendel in the later part of the 19th century gave rise to the laws of heredity and formed the basis for extensive scientific research into the inheritance of traits in plants. A major breakthrough was the development of the hybridisation system (Van den Belt and Keulartz, 2007). Based on this technology, pioneer companies such as Bruinsma introduced the first F1 hybrid tomato in 1946, Pannevis introduced F1 cucumbers in 1957, and Rijk Zwaan and De Ruiter produced their F1 cucumber cultivars in 1958. These companies usually made use of half-materials derived from breeding research institutes such as the Institute for Horticultural Plant Breeding (IVT) in Wageningen. The success of breeding companies was highly dependent on well-characterized genetic material (germplasm) that needed to be accumulated and characterized over a long period by specialized R&D personnel that developed the new cultivars. As a result, the threshold for new entrants to the sector became high. When the F1-hybrid technology became dominant in breeding (NTZ, 1992), some domestic mergers and acquisitions took place between 1960 and 1980 (e.g. Van den Berg Brothers was acquired by De Ruiter Seeds). And since 1945, no new VBCs have been founded, except for Takii Europe, as a subsidiary of the Japanese breeding company in 1984 and Agrisemen, a spin-off company of Syngenta in 2001.

The discovery of the double helix structure of DNA by Watson and Crick in 1953 contributed to the development of molecular tools for plant breeding like genetic modification (recombinant DNA technology; transgenesis) in the 1980s, 'marker assisted selection' (MAS), and other 'molecular marker' technologies in the 1990s (Schenkelaars et al., 2011). Biotechnology showed great promise, but required more investment and was highly knowledge-intensive. The formation of Zaadunie in 1963 marked the start of a wave of mergers and acquisitions, which peaked in the 1990s, with the aim of achieving economies of scale for capital and knowledge intensive-investments (Figure 3.1). As a result the vegetable seed industry consolidated to about a dozen companies, which is the case today.

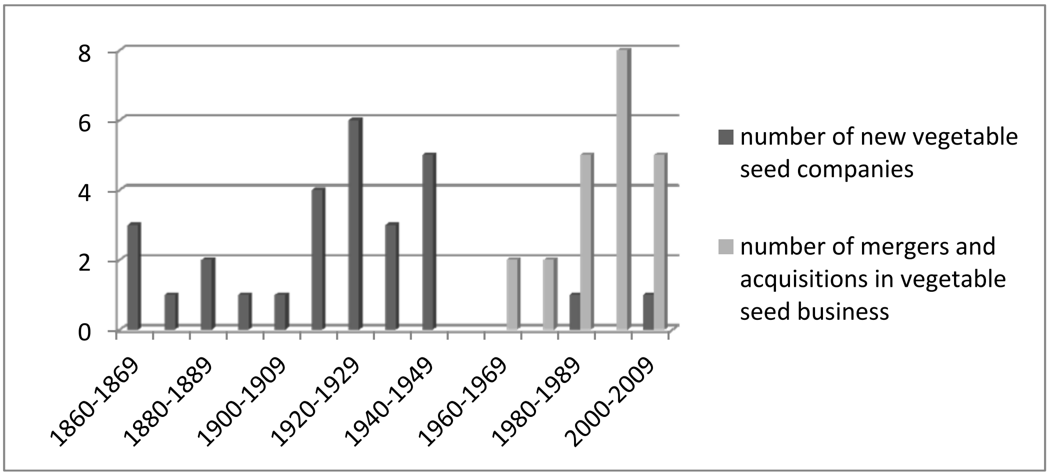


Figure 3.1 Evolution of the vegetable seed business in the Netherlands - Number of new vegetable seed companies and number of mergers and acquisitions over the past 150 years

Sources: NTZ, 1992; websites, authors

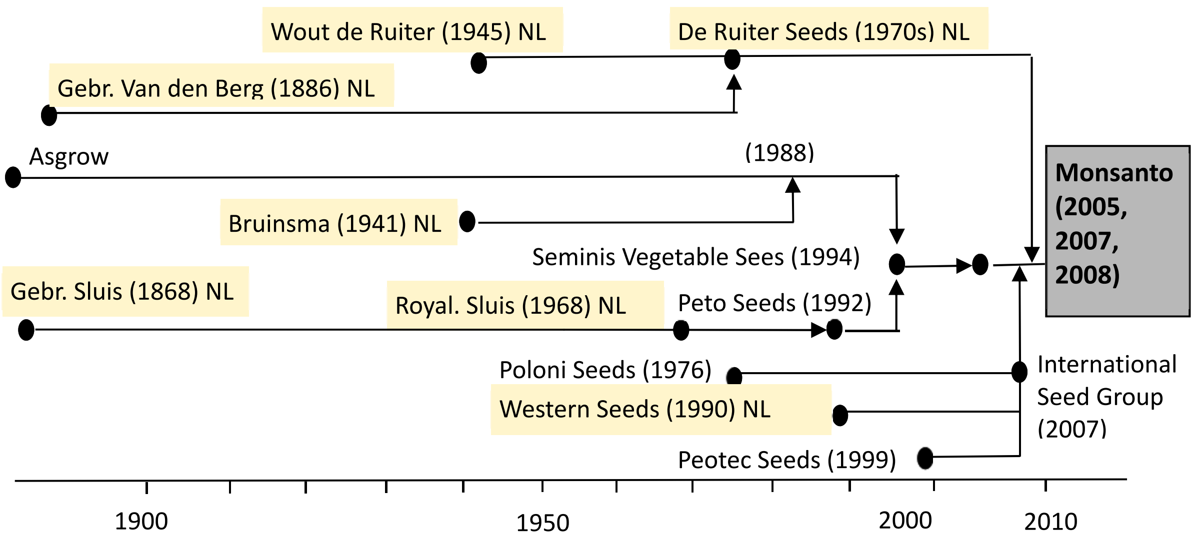


Figure 3.2 Historical overview of mergers and acquisitions that led to the current Monsanto vegetable seed business

Sources: (NTZ, 1992) websites, authors

The introduction of biotechnology in the R&D of breeding companies since the 1980s has initiated a large number of international mergers and acquisitions. To take a closer look at the merger and acquisition history of the vegetable seed industry in the Netherlands, I use Monsanto, the largest vegetable breeding company in the world, as an example (Figure 3.2). Monsanto became active in the vegetable seed business only recently in 2005, when it acquired the Mexico-based company Seminis, at that time the largest vegetable breeding company. However, Monsanto's vegetable seed business in the Netherlands can be traced back even to 1868 and now includes originally Dutch companies e.g. Bruinsma, Royal Sluis and De Ruiter Seeds.

As a result of all mergers and acquisitions of the last few decades, the vegetable breeding industry has become much more consolidated. Today there are only a few, but big players in the world. Many of the top ten companies were either founded or have important R&D stations in the Netherlands. Figure 3.3 shows the ranking of the main VBCs in the world. The total turnover of these 10 companies in the professional seed business was about 2,700 million Euro in 2011, which was 85% of the world's turnover of vegetable seed (LEI, 2012). Table 3.2 presents the links with or the presence of these companies in the Netherlands, indicating again the importance of the Netherlands in the vegetable breeding industry.

Table 3.2 The world's top ten vegetable breeding companies and their links to the Netherlands

Top 10 company	Parent company	Original country	Links in the Netherlands
1. Monsanto Vegetables	Monsanto	USA	Monsanto Vegetables has several roots in the Netherlands going back to Sluis Brothers in 1868 (details in Figure 3).
2. Vilmorin & Cie	Groupe Limagrain	France	Vilmorin & Cie acquired Nickerson-Zwaan in 1990 which is a Dutch vegetable breeding company.
3. Syngenta Seeds	Syngenta	Switzerland	Syngenta Seeds resulting from a series of mergers and acquisitions, with a Dutch root that can be traced back to Sluis and Groot, founded in 1867.
4. Nunhems	Bayer Crop Science	Germany	Nunhems is a Dutch breeding company founded in 1919, and acquired by Bayer in 2002.
5. Takii	Independent	Japan	Takii is a family-owned company founded in 1835 in Japan, and established their European subsidiary in the Netherlands in 1984.
6. Rijk Zwaan	Independent	The Netherlands	A family-owned Dutch company founded in 1924.
7. Sakata	Independent	Japan	Sakata was founded 1913, and established their trade office Sakata Holland in the Netherlands in 1990.
8. Enza Zaden	Independent	The Netherlands	A family-owned Dutch company founded in 1938.
9. Bejo Zaden	Independent	The Netherlands	A family-owned Dutch company with roots back to 1899.
10. Fito Semillas	Independent	Spain	A family-owned Spanish company founded in 1880.

Source: information from interviews and websites

Globalization

The vegetable breeding industry in the Netherlands has always been driven not only by developing innovative new cultivars, but also by trading seeds within an expanding international market (Figure 3.4). Furthermore, its exports are much higher than its imports. This is explained by the fact that vegetable seeds are produced in many different locations across the world, then imported into the Netherlands for processing and packaging, and then exported again to growers worldwide. Nowadays, the seed business is a global business, and all large companies have very wide international networks of commercial offices, research facilities and distributors. Furthermore, this globalization stimulates and enables VBCs to access knowledge worldwide. Eight out of the ten companies that were interviewed in this study indicated that at least one of their top five most important innovation partners is not located in the Netherlands. Their main foreign innovation partners are universities and research institutes, other breeding companies, and customers worldwide.

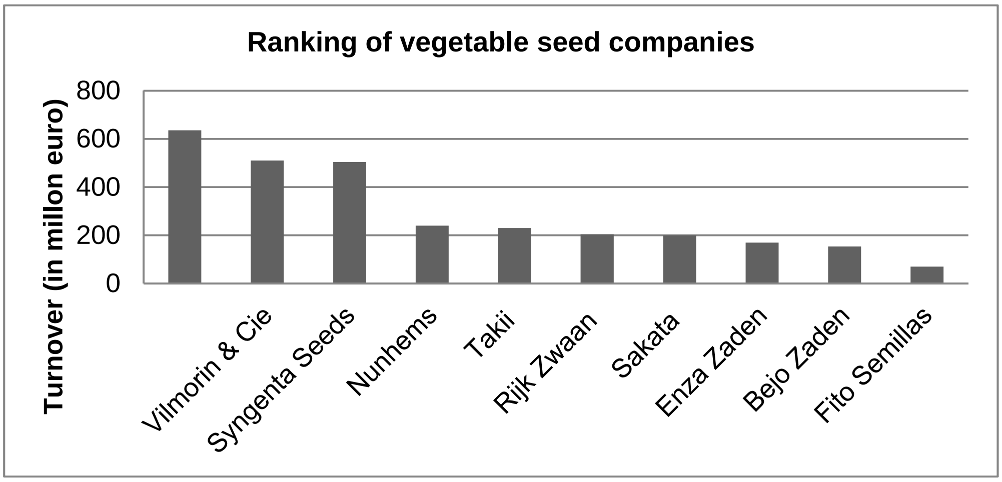


Figure 3.3 Turnover in seed sales in 2011 of the world's top ten VBCs
Source: information from interviews and websites

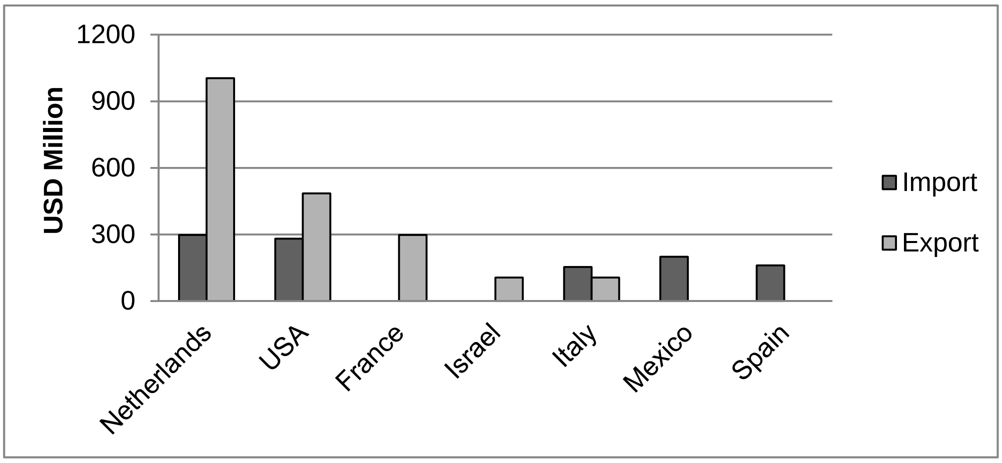


Figure 3.4 Top five countries exporting and importing vegetable seeds
Source: (ISF, 2011b)

Innovation driven vegetable breeding companies

Plant breeding companies are well recognized for their high level of innovation. Looking at the total expenditure in R&D of all the companies in the Netherlands, well-known big multinational companies like Philips, ASML, Shell, DSM and Unilever are in the top five. But positions 12, 16, 18 and 23 are taken by respectively Rijk Zwaan, Nunhems, Enza Zaden and Keygene (a Dutch plant biotechnology company, see Section 3.4.5), all representing Dutch companies active in R&D in the plant breeding industry (Technisch Weekblad, 2011). The Dutch plant breeding industry was reported to invest on average 15% of its turnover in R&D each year (LEI, 2012), but in this study it was found that the level of R&D investment of VBCs is even higher.

Table 3.3 Basic information on two types of vegetable breeding companies in the Netherlands

	Min.	Max.	Mean			
			Average	Private-[1] Small	Private-[2]large	[3]Part of multinational
1. number of employees	12	4,000	1,150	31	1350	2067
2. turnover 2010 (million Euro)	3.2	594.0	192.2	14.1	169.0	345.3
3. number of R&D employees	6	1,100	372	7	508	600
4. R&D budget (% of turnover)	9%	35%	19%	22.0%	23.0%	13.8%
5. R&D employees (% of total employee)	12%	50%	32%	31.0%	36.3%	29%
6.company age (year)	10	94	46	32	60.0	52

[1]Small: 10-100 employees; [2] Large: with more than 1000 employees; [3] Part of multinational, Takii Europe is excluded from this group, because it is the subsidiary of a family-owned company, which is quite different from multinationals

Table 3.4 Priority of research activities valued by vegetable breeding companies in the Netherlands

	Priority (1-7, 1-lowest, 7-highest)			
Research activities	[1]Private-Small	[2]Private-Large	[3]Part of multinational	Average
Breeding and selection of new cultivars	7.0	7.0	7.0	7.0
Use of molecular markers	5.0	6.7	7.0	6.3
Phytopathology research	4.0	6.7	6.8	6.2
Seed technology (e.g. quality control, seed	4.5	6.7	6.0	5.8
Collection of new germplasm resources	5.5	6.3	5.8	5.7
Plant tissue culture(e.g. DH production)	2.0	6.3	5.9	5.1
Basic research (e.g. new breeding methods)	4.0	6.0	4.5	4.9
Genomics and bioinformatics	1.0	5.3	6.0	4.5
Use of genetic modification (GMO)	1.0	2.0	3.4	2.3

[1]Small: 10-100 employees; [2] Large: with more than 1000 employees; [3] Part of multinational, Takii Europe is excluded from this group, because it is the subsidiary of a family-owned company, which is quite different from multinationals.

Our survey of all ten vegetable breeding companies in the Netherlands (Table 3.1) resulted in basic information concerning size, turnover, company age and research investment (Table 3.3). These results show that on average now even 19% of the turnover was used for product and process innovation, and 32% of the employees are working in R&D. The R&D budget of one company was even 35% of turnover, and the number of employees involved in R&D represented up to 50% of total staff. Such figures clearly illustrate the importance of innovation in this industry. The companies can be divided into different types. I differentiated the private family-owned companies into two subgroups: private-small (10-100 employees) and private-large (more than 1000 employees) companies. In this analysis, Takii Europe was excluded from the group of multinationals because of its special structure. It is a European subsidiary of a Japanese family-owned company. This makes it quite different from the other four multinationals that are publicly listed companies. In general, private-small companies are not only much smaller than the private-large and multinational companies in terms of number of employees and in terms of turnover, but especially in the number of R&D employees, which is only about 1% of the number in the other two groups. Private-large companies are much smaller than the multinational companies, but have the longest history, highest R&D investments and highest percentage of R&D employees.

Various R&D activities and the priority were studied that was given to those activities (Table 3.4). As expected the breeding and selection of new cultivars was given the highest priority by all companies, as it is the core R&D target of breeding companies. Genetic modification received the lowest priority, due to the limitations on the application of this new technology imposed by politics, legislation and regulations and its low public acceptance in Europe. Furthermore, there were differences between groups. Small-private breeding companies gave less priority than other groups to using technology, such as molecular markers, genomics and bioinformatics, and genetic modification. This might be due to their small size generating fewer funds for the acquisition of capital-intensive technologies.

Innovation and intellectual property protection

The high expenditure in R&D shows that innovation is crucial in the vegetable breeding industry. Another good indicator for innovation in the breeding industry is the number of new cultivars for which Plant Breeders' Rights (PBR) / Plant Variety Protection (PVP) has been obtained. This intellectual property rights (IPR) system has been developed specifically for the plant breeding industry and allows breeders a monopoly position for a limited (usually about 20 years) time. The owner of the protected variety is the only one to commercialize said cultivars. Breeding companies from the Netherlands hold 32% of all European PBRs, and they even account for 55% of all PBR's in vegetable crops.

Specific examples are lettuce (67%), French beans (46%), and tomatoes (42%) (GHK and ADAS., 2011). This outstanding position of the breeders in the Netherlands is the result of a combination of high-quality germplasm, innovative breeding programs, high R&D investments and a good intellectual property protection system to encourage continuous innovation.

The PBR system plays an important role in the stimulation of innovation in the breeding industry, because it ensures that the breeder of the variety will have a good return on investment. At the same time innovation in the whole industry is stimulated thanks to the so-called "breeder's exemption" that allows all other breeders to use the protected material for further breeding. The introduction of biotechnology in the plant breeding industry since the 1980s has also initiated the use of patents to protect intellectual property. Between 1980 and 2008, a total number of 9,456 patent applications in the field of plant breeding were filed internationally (at WIPO and EPO) (Winnink, 2012). An analysis of the applicants shows that, as expected, the large multinational breeding companies and also three public research organizations are listed in the top-10 (Table 3.5). In the context of this research it is important to note that Wageningen UR in the Netherlands also has a high ranking at position 14 with 87 patent applications. This underpins the important position of this research organization in the field of plant breeding research (also see section 4.2 on the research & education domain).

Table 3.5 Top applicants of plant breeding patents at WIPO and EPO in the period 1980-2008

Company/organization	Patent applications	% of the total number of applications
1. Pioneer Hi Bred	522	5.4 %
2. BASF	491	5.2%
3. Monsanto Co	487	5.1%
4. DuPont de Nemours	360	3.8 %
5. Syngenta	303	3.2 %
6. Bayer	238	2.5 %
7. UC Davis	173	1.8 %
8. Astra-Zeneca	124	1.3 %
9. Commonwealth Sci. and Ind. Res.Organization	106	1.1%
10. Canada Nat. Res. Council	105	1.1%
14. Wageningen UR	***87***	***0.9%***

Source: (Winnink, 2012)

In total, about 5 % of all patent applications in this period were from inventors in the Netherlands. If taking a closer look at the patent applications from the Netherlands (Table 3.6), Wageningen UR is the leading organization, but the main breeding companies having R&D in the Netherlands have a high ranking. The patents filed by companies and research organizations can be divided over three types of biotech patents: 1) Plant breeding processes: 31,0 %; 2) Products as a result of plant breeding: 62,2 %; 3) DNA-related technologies for plant breeding: 83.3 % (these percentages do not add up to 100% because patents can fall in more than one category). Therefore, most applications deal with DNA-related technologies, which is a clear reflection of the impact of the new field of molecular breeding, e.g. the use of molecular markers and the introduction of new genes in transgenic plants.

Table 3.6 Top 20 Dutch applicants of plant related patents submitted at WIPO of EPO in the period 1980-2008

	Company/organization	Number of requests	Share in requests submitted at WIPO or EPO
1	**Wageningen UR**	**87**	**0,90%**
2	Unilever	56	0,58%
3	Mogen Int.	54	0,56%
4	University Leiden	29	0,30%
5	Keygene NV	27	0,28%
6	Rijk Zwaan	27	0,28%
7	AVEBE NV	18	0,19%
8	De Ruiter Seeds	16	0,17%
9	Syngenta	15	0,16%
10	Royal Shell Group	14	0,15%
11	EnzaZaden	12	0,13%
12	Expressive Res. BV	11	0,11%
13	Nunhems BV	10	0,10%
14	Advanta Seeds	9	0,09%
15	BASF	9	0,09%
16	Gist Brocades	8	0,08%
17	STW (foundation for technological research)	8	0,08%
18	Bejo Zaden BV	7	0,07%
19	DSM NV	6	0,06%
20	Binary Vector System Foundation	6	0,06%

Source: (Winnink, 2012)

Supply chain cooperation of the VBCs in the Netherlands

VBCs are the starting point of the vegetable supply chain. Their breeding activities affect all partners in the chain from grower, trader, processor, retailer to the consumer (Dons and Bino, 2008), and the value of the products is multiplied during the various steps in the supply chain. For example, for one kilogram of tomato seeds the grower has to pay around 75,000 euros. From this kilogram of seeds he can harvest tomato fruits with a value of 4,250,000 euros, which is 50 times the unit of seeds. On the other hand the retailer can earn up to 8,500,000 euros with the same amount of seeds (Figures from 2011). This shows that in this industry the competition is much more focused on the quality of the cultivar and the seed than on the seed price.

Not only the breeding companies are highly innovative but also the other stakeholders further downwards in the supply chain are recognized for their innovative strength. All VBCs collaborate with processors of seeds, such as Incotec, and Holland Processing. They develop sophisticated equipment to improve quality and efficiency in seed production and processing. Furthermore, there are several collaborations between partners in the supply chain. For example, farmers are organized in cooperatives, such as Coforta, a cooperative of about 900 affiliated growers that owns the whole subsidiary company Greenery, which closely co-operates with the plant breeding companies on the one hand and supermarkets on the other. They collect market information and deliver that demand to plant breeding companies. Supermarkets account for over 80% of the market share of vegetable retail in the Netherlands (Plaggenhoef, 2007), and among the 10 VBCs in the Netherlands that were studied, half of them had collaborations with supermarkets and used this market information in their strategy for developing new cultivars. Some VBCs even signed exclusive contracts with supermarkets to sell specific varieties. Several VBCs also indicated they had R&D projects with vegetable processors, such as vegetable packers of spinach, and producers of Sauerkraut who use cabbage as basic material.

3.4.2 Research & education domain

The prosperous development of the breeding industry in the Netherlands is not only based on the well-structured business domain, but is also strongly supported by the agricultural research & education domain, which plays an important role in the knowledge flow that was essential for the development of the industry.

Consolidation of agricultural research and education

Agricultural education has a long history in the Netherlands. As early as 1876 the State Agricultural School (Rijkslandbouwschoool, the predecessor of the Agricultural University) was founded in Wageningen, with the objective of offering education to young people and training them to become well-educated farmers (Maat, 2001). The founding occurred during a crisis caused by the increasing competition of agricultural products from America in the 1880s, when other European countries, such as France and Germany, resorted to protectionist measures, while the Netherlands chose to invest in research and education to improve competitiveness and productivity of the sector.

As a result of this policy, in 1912, the Institute for Plant Breeding (Instituut voor Plantenveredeling - IvP) was founded for the improvement of agricultural crops. For the breeding industry in the Netherlands a further crucial development was the foundation of two new research organizations in the 1940s: the Institute for Horticultural Plant Breeding (IVT, Instituutvoor de Veredeling van Tuinbouwgewassen), which was a public research institute created in 1943, which carried out research programs ranging from fundamental plant breeding research to the development of cultivars, and closely cooperated with private plant breeding firms (Hogenboon, 1983). The second was the Foundation for Plant Breeding (SVP, StichtingvoorPlantenveredeling), which was established by the Dutch plant breeders association in 1948, with the aim of supporting the work of breeders and breeding companies with additional research that might result in commercial applications in the long run (Maat, 2001). These research institutes have contributed significantly to the further professionalization of the breeding industry in the Netherlands and in other countries.

These two research institutes were part of large investments in research and education in the post-World War II period, and resulted in an extensive network of research organizations, agricultural schools and extension organizations. Around 1985 more than 200 institutions were involved in agricultural and horticultural research in the Netherlands (Van der Valk et al., 2009). This agricultural knowledge system, put in place in the second half of the 20th century, was famous and became a model for other countries. The system was known as the REE-tryptich which stands for the integration of Research, Education and Extension (in Dutch: OVO for Onderzoek, Voorlichting, Onderwijs) (Dons and Bino, 2008). This organization has changed and consolidated dramatically over the past twenty years. The main reasons for this were the transformation from a knowledge-driven research to a demand-driven research and the governmental decision to consolidate the research institutes (Van der Valk et al., 2009). As a result, a major reorganization of agricultural research in the Netherlands took place from 1987 to 2004, culminating in the creation of Wageningen University and Research Centre (Wageningen UR), an alliance of Wageningen University, the research institutes of the Dutch Agricultural Research Department (DLO), the experimental stations and the Higher Education Institute of Van Hall Larenstein(Dons and Bino, 2008). The University groups as well as the research institutes responsible for research and education in plant breeding all became part of this organization. Besides Wageningen UR, there are other Dutch universities active in the field of plant biology and biotechnology disciplines, which are relevant to the breeding industry. However, since plant research, as well as plant breeding research, is largely concentrated within Wageningen UR, the following analysis of the Dutch agricultural research & education domain will be focused on Wageningen UR.

Currently Wageningen UR is divided into five expertise groups: (1) Plant Sciences, (2) Animal Sciences, (3) Agrotechnology and Food Sciences, (4) Environmental Sciences, and (5) Social Sciences. In each expertise group, the fundamental, strategic and applied research departments share the same central management. The applied research is close to the day-to-day practices of farmers and growers, and the strategic research is mostly organized along subsidized thematic research programs in which major stakeholders participate together with industry (Kamphuis, 2005). Fundamental research is research at an academic level within the University part of the organization.

After the reorganization that resulted in the creation of Wageningen UR, including a new infrastructure within a centralized campus, interactions between research and education have improved and synergistic benefits have emerged. For example, in the Plant Sciences Group, most of the 1,600 researchers have worked at the same location in Wageningen since 2009, whereas before they merged into Wageningen UR they were located at different research centres throughout the country. A recent peer review report said that this situation creates daily opportunities to work together in the same laboratories and meeting rooms, thereby greatly facilitating the informal exchange of views and ideas (WUR, 2009). Furthermore, a study of Terheggen and Leemans (2010) showed that at Wageningen UR relatively large numbers of joint multidisciplinary publications are produced.

The international collaboration of Dutch plant sciences

Wageningen UR has achieved a prominent position within the agricultural sciences. This can easily be deduced from an international analysis of scientific publications and citation indices. Among the most influential and widely observed international university rankings, Wageningen UR ranked number one in the field of agricultural sciences (Academic Ranking of World Universities (Shanghai Ranking), 2012; Taiwan Ranking, 2012), and ranked number 22 in the field of life science (Times Higher Education World University Rankings, 2012).

For the purpose of this chapter, I analysed the degree of international collaboration of Wageningen UR and its predecessors by examining the worldwide network of authorships of the top 1% scientific publications in plant genetics, plant molecular biology, and plant breeding (2011) from 1945 to 2012 (as explained in the methodology section). The percentage of top cited papers with an international authorship increased substantially over time, and accounts for nearly half in the latest period (Table 3.7).

Table 3.7 Number of international top 1% papers in plant breeding and biotechnology in different periods

Years	Number of top 1% papers	Number of international top 1% papers	% of the international papers
1945-1980	26	0	0%
1981-2000	108	12	11.1%
2001-2009	195	52	26.7%
2009-2012	89	38	42.7%
Total	418	102	

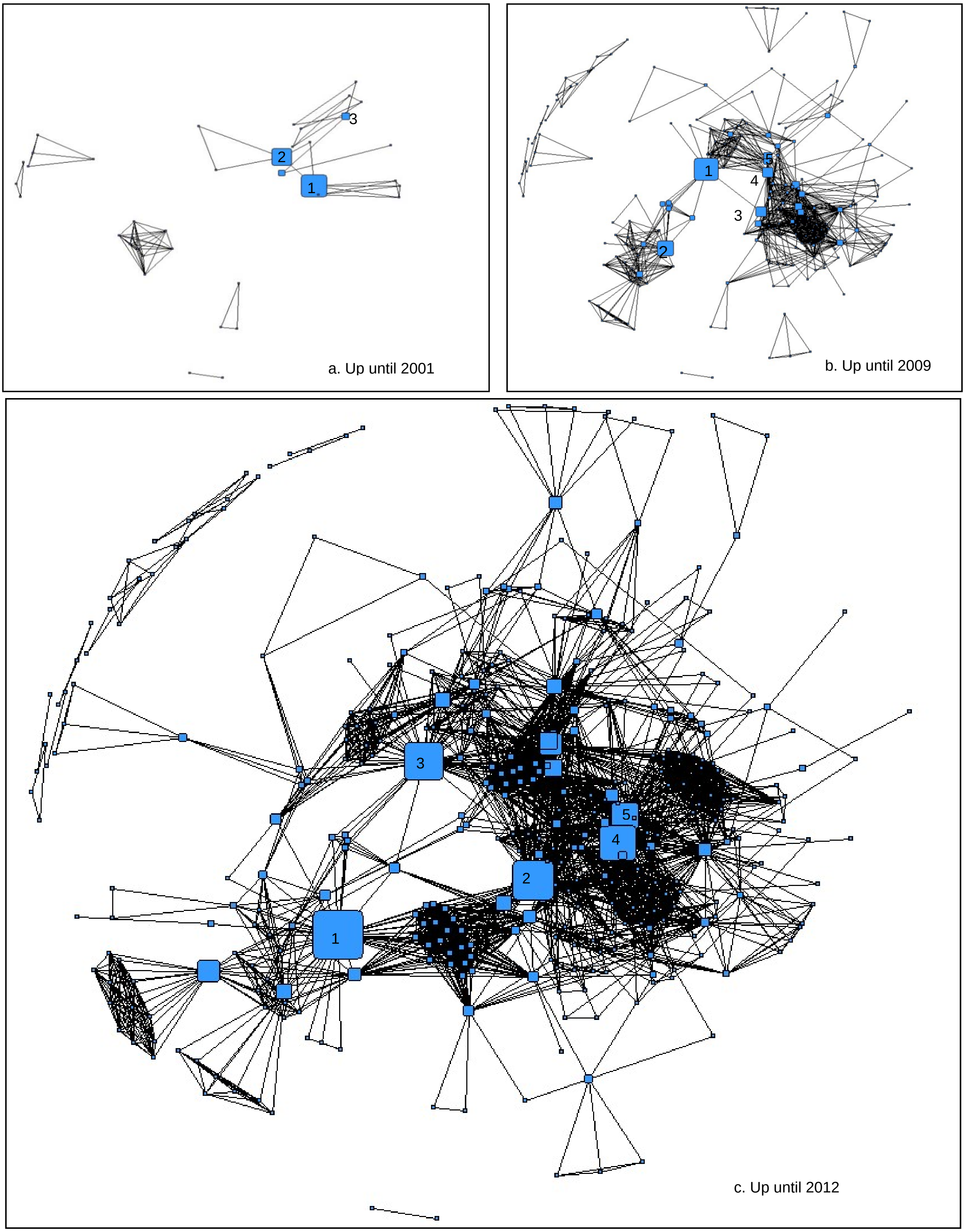


Figure 3.5 Global collaboration maps of plant breeding and biotechnology research a. up to 2001, b. up to 2009 and c. up to 2012

The co-authorship data of these top 1% scientific publications was used to map the global collaboration in plant breeding and plant biotechnology by using UCINET, a social network analysis software. In Figure 3.5, the nodes represent the different research organizations, which published the top 1% cited papers as a result of joint research with international partners. The lines in-between indicate that there were collaborations (joint publications) between the institutions. The calculation by UCINET shows that the larger the node, the higher the centrality of a research organization in the global collaboration (Figure 3.6). Up until 2001, the top research organizations in the centre of collaborations were 1) John Innes Centre; 2) University of California Berkeley; 3) Mogen International; 4) Purdue University. The analysis up until 2009 shows that Wageningen UR already hold the second position after 1) French National Institute for Agricultural Research (INRA) and before 3) John Innes Centre; 4) Purdue University and 5) University California Berkeley. In the analysis up until 2012, however, Wageningen UR was holding the top position as centre of international collaboration with 2) University of Wisconsin; 3) INRA; 4) Cornell University and; 5) United States Department of Agriculture (USDA). This analysis clearly underlines the central role of Wageningen UR in the fields of plant breeding and biotechnology.

Students in agricultural sciences

For the development of a knowledge-intensive industry it is important to have a good inflow of talented scientists. Therefore the number of students in the agricultural sciences and more specifically in plant sciences was studied. Figure 3.6 shows that the total number of students at Wageningen UR and its predecessors increased over the years to over 7,000 in 1988. Then the number decreased substantially in the nineties extending into the first years of the new millennium, to about 4,000 between 1999-2000. This decrease was most prominent with male students, and since then women have overtaken men in terms of student numbers. Since the beginning of 2000, at a moment when the university was undergoing a large restructuring of the agricultural research organizations, which resulted in the establishment of Wageningen UR, which was further promoted as a university for life sciences instead of an agricultural focused institution. Indeed, the dip in the number of students in the 80s and 90s may reflect the loss of traditional students interested in agricultural research and education and the replacement by a new student group interested in the study of life sciences. As a result the number of students has been increasing substantially since then. There were a total of over 7,000 students again in 2011.

Looking specifically at the number of graduates in plant sciences, Figure 3.7 shows a decrease in graduates between 1990 and 2010. However, these low numbers are gradually recovering now thanks to the rapidly increasing number of international students. This was induced by the fact that the MSc. programs are now all taught in English, and also have a high reputation that attracts students from abroad. Although these figures are promising, the interviews with senior managers of seed companies shows that the numbers of students in plant sciences are not yet sufficient to satisfy the demands for talented people needed in the breeding industry.

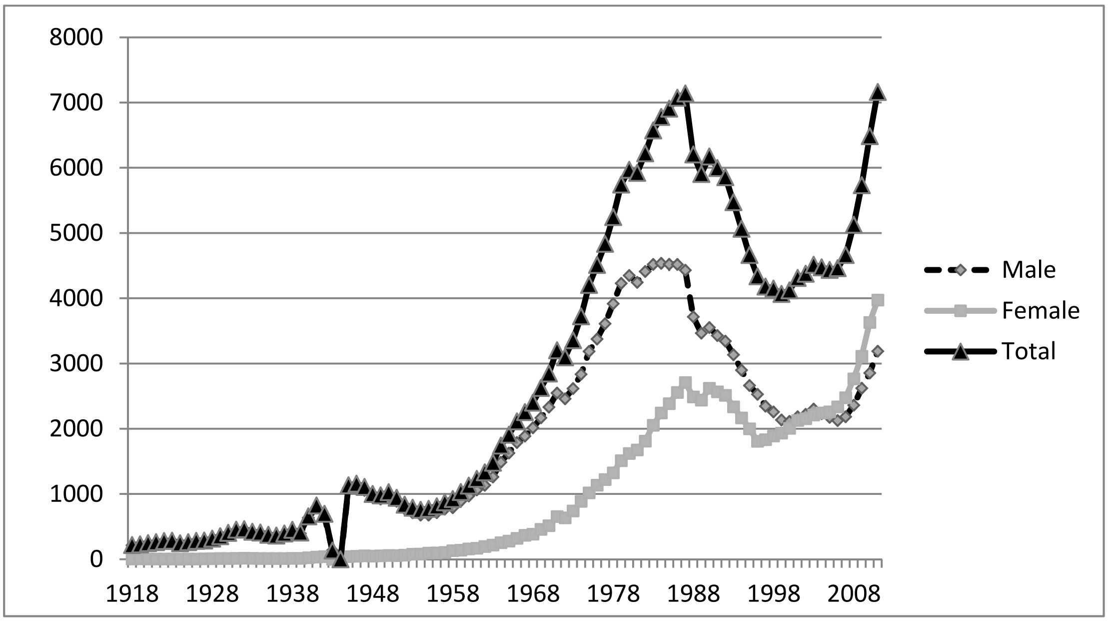


Figure 3.6 Number of students at Wageningen UR 1918-2011

Note: The dip between 1940 and1945 reflects World War II

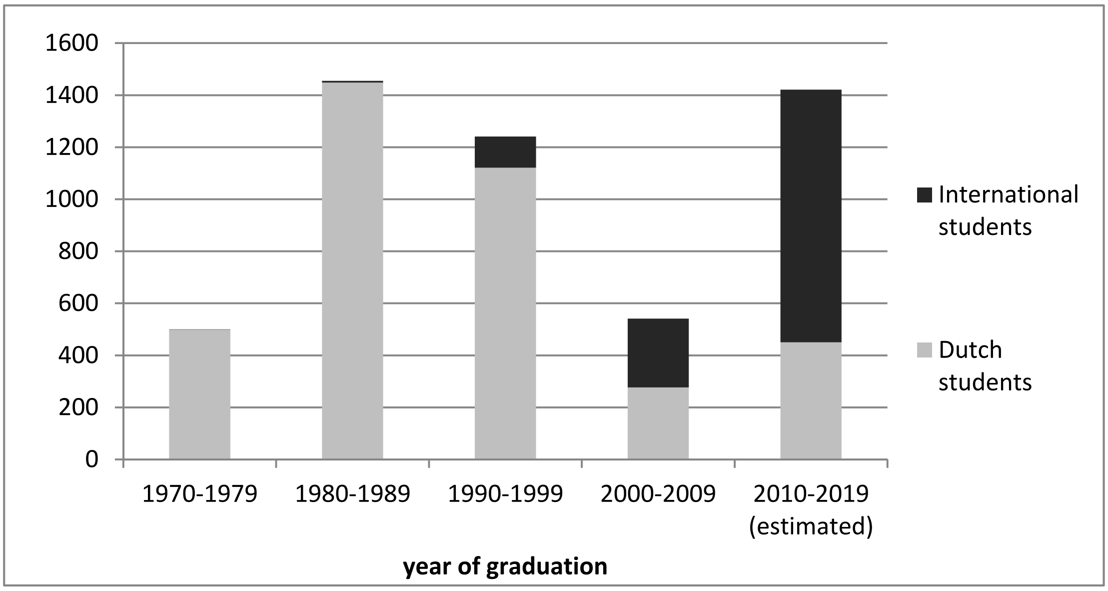


Figure 3.7 Number of graduates in plant sciences at Wageningen UR.

Note: The number for the period 2010-2019 is an estimate based on the number of students currently present.

3.4.3 Intermediate organizations

Public-private partnerships in agricultural research and education

Over the years, significant changes have taken place, not only in the research & education domains, but also through the interactions between the breeding industry, research institutes and education institutes. In the past, the classic flow of knowledge began with fundamental research at the university via strategic and applied research, at governmental research institutes and experimental stations, which was then transferred to practical implementation via agricultural extension systems following the REE tryptich system mentioned before (Dons and Bino, 2008). Nowadays, the Dutch agricultural research & education domain has changed from this classical transfer model towards new concepts of co-innovation. Several public-private partnerships have been established, in which various stakeholders work closely together in dynamic and open systems. Figure 3.8 shows such a model for the breeding industry.

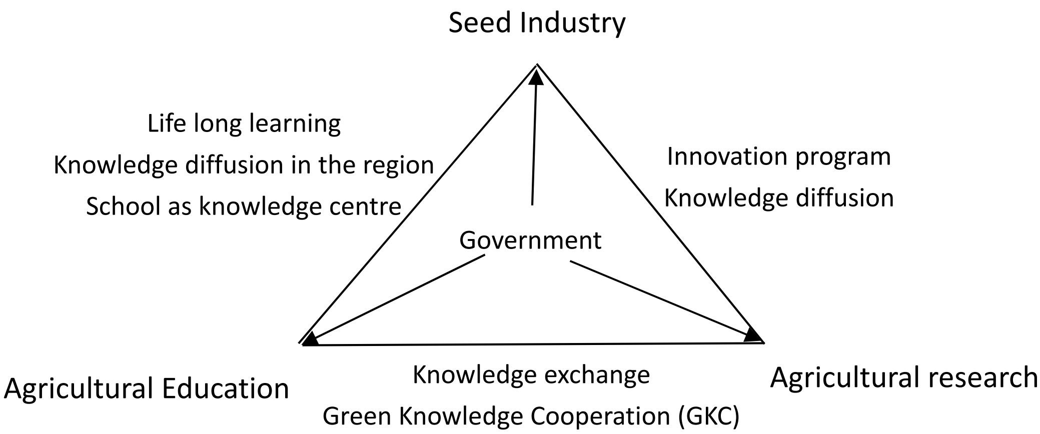


Figure 3.8 Public-private partnerships in the breeding industry in the Netherlands
Source: Adapted from (Poppe, 2011)

The exchange of knowledge is facilitated by a close interaction among various stakeholders in the education and research domain. An interesting example is the Green Knowledge Cooperative (GKC), an education consortium for the agricultural industry, with 13 ‘green’ schools for primary and secondary vocational education, 5 ‘green’ colleges (BSc) of applied sciences and Wageningen UR for academic education (MSc) and research (PhD). GKC focuses on making scientific knowledge accessible to educational programs within these universities and schools, and aims at establishing networks and shared facilities, characterized by strong and close links between research, education, industry and government (Wageningen UR, 2012). Besides mainstream education, it also offers a broad range of special training courses for farmers and others involved in this industry. Life-long learning and knowledge diffusion in regional schools is encouraged and agricultural education and the breeding industry.

Co-innovation and knowledge dissemination are also facilitated by research institutes and the breeding industry through cooperative research programs in which both research institutes and VBCs participate, and which are partly funded by the government. Examples of such Public-Private-Partnerships (PPP) are the Centre for BioSystems Genomics (CBSG) and the Technological Top Institute Green Genetics (TTI-GG).

CBSG is a consortium of major Dutch and international breeding companies and top plant scientists working on three important food crops: potato, tomato, and Brassica. It is a PPP in plant genomics including two universities, four research institutes, six VBCs, five potato breeding companies, one potato processing company, one genomics technology company and two potato commodity boards. CBSG was established in 2002 with a total research budget of 100M€ for 10 years. The funding came from the Netherlands Genomics Initiative, the industrial partners and the matching from the participating knowledge institutes. CBSG carries out plant genomics research using the latest, state-of-the-art technologies. The number of crops is restricted in order to maintain focus and to cover crops of greatest importance for the Dutch agriculture and food industry (Leone, 2007).

Omta and Fortuin (2010) investigated the expected contribution of CBSG to innovation in the industry. The impact of CBSG research is visualized in Figure 3.9. The CBSG research organization was financed via a combination of public subsidies and private direct and indirect funding, in the expectation that investments in fundamental and strategic research projects would benefit the whole research infrastructure. Such an improved public research infrastructure stimulates the industry to further invest in research programs linked to CBSG. Thus, as CBSG research is enhancing breeding knowledge, more new products (improved cultivars) are expected to be developed, and innovation cycle times to be shortened. These will increase the innovation rate and enhance the competitive strength of the industry. One of the interesting results of the survey was that some companies expected a time reduction of up to 30-40% and other companies indicated a 5 - 25% cost reduction in their breeding activities.

The impact of PPPs on the research infrastructure can easily be visualized by the changes in funding of the Plant Breeding Research Group of Wageningen UR (Figure 3.10). In the period from 2008 to 2011, the budget for contract research with companies decreased from 20% of total turnover in 2008 to 6% in 2011 whereas the percentage of funding via PPPs grew substantially from 4% in 2008 to 31% in 2011 (Wageningen UR, 2012).

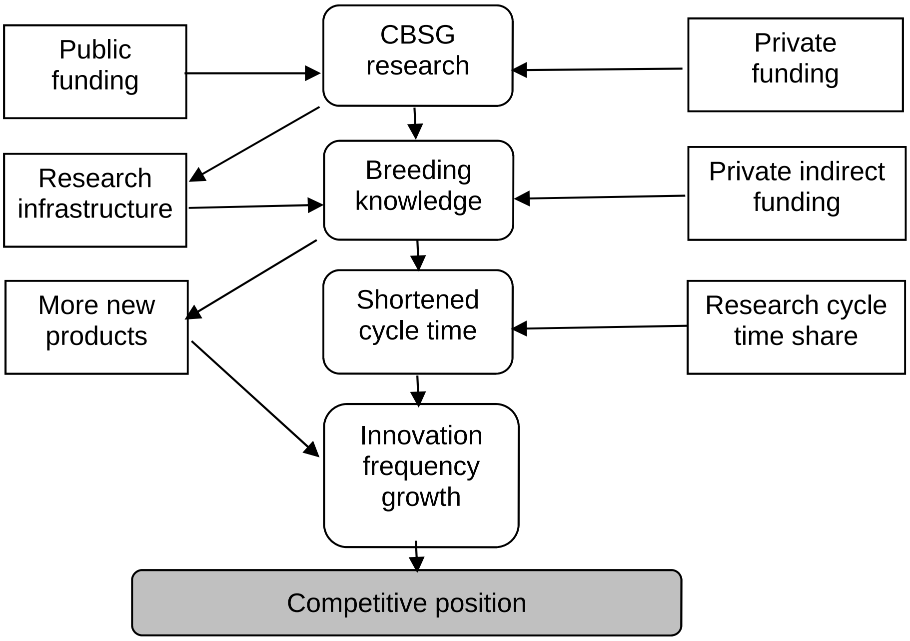


Figure 3.9 Organization of CBSG Research and expected impact on Industrial Partners
Source: Omta and Fortuin, 2010

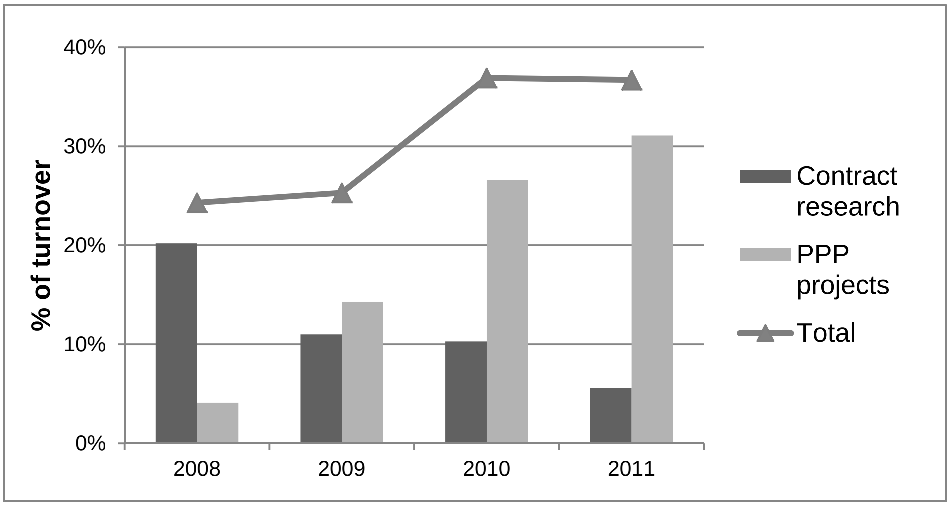


Figure 3.10 Contract research and PPP projects as percentage of total turnover of Plant Breeding Group of Wageningen UR from 2008 through 2011

Based on the success of the PPPs, in 2012 the Dutch government decided to continue this innovation model through the creation of so-called Top Sectors, sectors that are selected on the basis of their economic importance. The plant breeding industry is represented in the Top Sector Horticulture and Starting material and new consortia of industrial partners and knowledge centres will be established to further improve the research and education infrastructure.

Branch organizations

Plantum is the Dutch association for breeding, tissue culture, production and trade of seeds and young plants. It is not just a platform for member companies to exchange information or collaborate, but it also very actively collaborates with the relevant stakeholders to find solutions to the challenges of biodiversity, organic plant reproduction material, crop protection, export and trade promotion, intellectual property issues, legislation and legal affairs. With the aim of improving the environment for innovation in the breeding industry, in 2009 Plantum initiated the debate on intellectual property rights in plant breeding that has resulted in a discussion at the European and global level and will result in the improvement of the Plant Breeder's Rights system and the patent rights system for plant-related patents (Louwaars et al., 2009). Moreover, Plantum also facilitates the creation of the necessary knowledge infrastructure together with knowledge institutes and the government. For example, the Technological Top Institute Green Genetics (TTI-GG) was founded on the initiative of Plantum. In the investigations it was found that all Dutch VBCs, both large and small ones, were actively participating in Plantum and were positive about the contribution of Plantum.

Naktuinbouw, the Netherlands Inspection Service for Horticulture, was founded about 70 years ago by seed companies to control the quality of seeds, but also to support the industry to improve the quality of their business. Nowadays, Naktuinbouw is an autonomous public authority regulated by the Ministry of Economic Affairs, with the aim of promoting and monitoring the quality of products, processes and chains in horticulture. Through this platform, issues of seed quality can be discussed, providing the possibility of influencing policies related to seed quality, and of supporting continuous innovation in seed quality. Naktuinbouw has an obligatory inspection system that applies the European directives and legislation for propagating material for horticultural crops. Moreover, a series of voluntary quality inspections are performed and complement the statutory inspections and even place more stringent demands. Such testing is carried out for producers of propagating material. Naktuinbouw is also involved in the development of systems designed to stimulate and spread knowledge in this industry, such as by organizing training courses. Naktuinbouw is also the official organization in the Netherlands that assesses new varieties for registration purposes and grants Plant Breeders' Rights (Naktuinbouw, 2012).

Seed Valley is a more recent (2008) initiative and refers to a specific area in the province of North Holland, home to many companies specialising in breeding, production and sales of high-quality seeds and basic plant material. This regional cluster also includes suppliers of services and equipment specific to the breeding industry. Seed Valley was established with the aim of reinforcing the economic position of the regional cluster, by investing in its image, and promoting the influx of skilled workers, innovation and the sharing of expertise.

3.4.4 Market demand

As the global population will continue to grow to more than 9 billion by 2050, the demand for more food higher in quality will increase dramatically, which is generally considered that crop production will have to be doubled by that time (FAO, 2006). It was found that one half of the enormous yield increase during 1947-1986 (the green revolution) could be attributed to plant improvement by breeding and the other half to an improvement in agricultural practices, in particular the use of fertilizers, crop protection and irrigation (Silvey, 1978). These agricultural inputs will become more scarce and expensive in the future, making the contribution of plant breeding even more important. Apart from a focus on yield, plant breeders also have to develop new varieties with resistance to biotic stress that causes worldwide losses of about 130 billion US dollars per year, and varieties with tolerance to abiotic stress, as 90 million people are affected by drought, 106 million by flooding, and 900 million hectares of soil are affected by salinity (Bruins, 2009a). Furthermore, several other aspects of crops have to be altered for the benefit of mankind, e.g. earliness, taste, size, nutritional value, firmness, shelf-life, plant type, labour costs and harvest ability (Bruins, 2009b).

In the vegetable industry, market demand is strong, as vegetables are important components of a healthy diet, and a sufficient daily consumption can help prevent diseases. Based on FAO statistic data, current production of the 15 vegetables studied has increased above 1980 levels ranging from 74% for sweet corn to 259% for spinach and eggplant. On a *per capita* basis worldwide, consumption of all 15 vegetables rose by double digits, with cabbage having the lowest (21%), and eggplant the highest (148%) growth (FAO and WHO, 2004). As described above, this worldwide increase in demand offers good opportunities for the internationally oriented Dutch vegetable seed business.

3.4.5 Infrastructure and framework conditions

"Polder culture" of collaboration

In discussions with all different stakeholders in the breeding industry on the main factors leading to success, collaboration with competitors and stakeholders was one of the most highlighted aspects. Collaboration allows actors to learn from each other's expertise and share the costs and risks. As mentioned before Public Private Partnerships (PPPs) are common practice in the Netherlands. There are more than 40 PPPs in the field of life sciences, including CBSG and TTI Green Genetics (Laane and Besteman, 2009) for the breeding industry in the Netherlands. Thus, the breeding industry in the Netherlands is characterized by a fierce competition, but also by intensive collaboration. Apart from the aforementioned PPPs there are also unique B2B collaborations between competitors to achieve mutual benefits. Intensive collaboration within small communities has been proposed as a cultural phenomenon in the Netherlands that was shaped over a period of over 900 years, starting in the 12th century with the need to reclaim and protect land (polders) among the river deltas and the sea. It has been argued that this "polder culture" has become an integral aspect of Dutch national identity (Schoubroeck and Kool, 2010).

A good example of such collaboration between competitors in the seed business is Bioseeds, a strategic alliance between VBCs. Starting in 1980, biotechnology became an important new discipline in R&D of breeding companies and in 1989 these companies founded Keygene, a plant biotech company. Its main focus was the development and application of new molecular breeding technologies that could speed up the breeding process, e.g. marker-assisted breeding. Dutch-based breeding companies (e.g. EijkZwaan, Enza Seeds) formed the core of the collaboration with Keygene. Its success attracted other foreign companies that became shareholders of Keygene more recently (Vilmorin&Cie, France; Takii, Japan)(Dons and Bino, 2008). All four companies belong to the world's top ten VBCs (Figure 3.3), and in interviews the managers of these breeding companies indicated that Keygene was recognized as their most important partner in innovation, and they expressed their satisfaction with its achievements.

Governmental support for an innovative industry

While the Netherlands is a small country with 17 million inhabitants and a relatively small number of scientists, 3% of all scientific publications come from this country, which consequently ranked 10th in 2010. If output is calculated as the number of publications per researcher, the Netherlands even ranks number two (behind Switzerland). In such statistics, the USA (No.1 in total publications) and China (No.2 in total publications) only hold positions 15 and 18, respectively (European Commission., 2011). These numbers show the high research output and high quality of research in the Netherlands, based on a good knowledge infrastructure. As shown in previous sections this also holds true for the domain of agricultural research, and more specifically for plant genetics and molecular genetics.

The Dutch government recognizes the importance of the breeding industry for the economy. As mentioned before (section 3.4.3), the government stimulates the interaction and co-operation between industry and research organizations via PPPs and Top-sectors. The Dutch government is also strongly involved in the discussions on IPR (section 3.4.1) concerning the balance between Plant Breeder's Rights and Patents on plant-related inventions (Dons and Louwaars, 2009).

3.4.6 Integrated picture of the sectoral innovation system of the vegetable breeding industry in the Netherlands

Based on the analysis made in the previous sections, an integrated picture of the vegetable breeding industry in the Netherlands is presented in the framework of SIS in Figure 3.11. The various stakeholders as well as some main characteristics of each domain as derived from this analysis are mentioned in the SIS diagram. The most important finding of this study is that there is a strong knowledge flow among the different domains of the SIS of the vegetable breeding industry in the Netherlands.

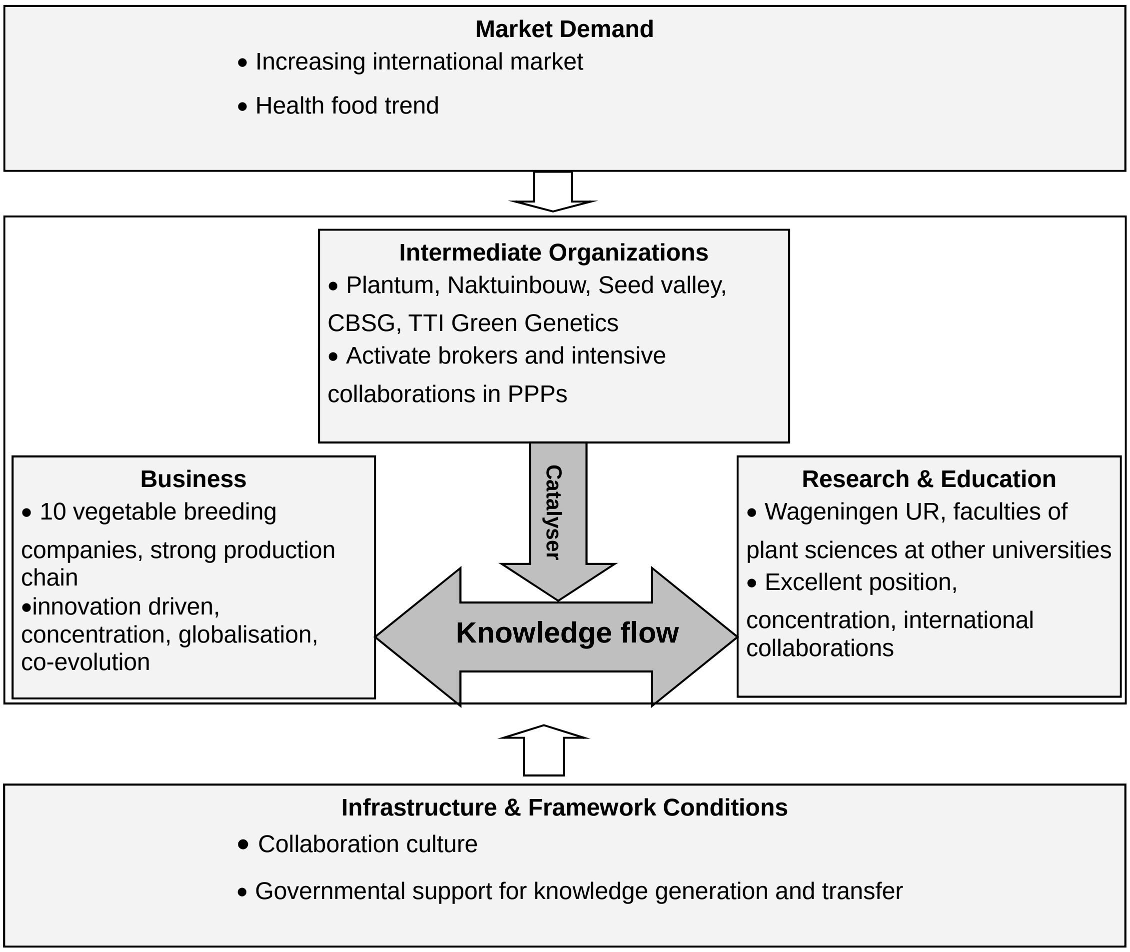


Figure 3.11 Integrated framework of the Dutch vegetable breeding sectoral innovation system (SIS)

Within the business domain the integrated vegetable breeding companies started as small family-owned companies characterized by craftsmanship and entrepreneurship. During the past century, these companies became more and more professional and internationally-oriented. They have developed due to their integration in a well-established business domain as well as a well-organized research & education domain. Nowadays, the vegetable breeding industry in the Netherlands is more consolidated. There exist only 10 companies that are active in breeding new cultivars, producing seeds and marketing & selling seed. These companies have strong international positions and are highly innovation driven. The companies spend on average 19% of their turnover on R&D, and make use of knowledge that is available worldwide. This intensive knowledge input and absorption capability has led to a high innovation output, leading to high-quality new cultivars, and a high ranking of Dutch companies and research organizations in the lists of PBR/ PVP and plant patents.

Within the research & education domain, Wageningen UR plays an essential role. Although there are other universities in the Netherlands that have plant science research departments, Wageningen UR is the dominant research and education institute in this SIS. The plant sciences, more specifically plant breeding research, at various levels of fundamental, strategic and applied research, were and are very important for the level of innovation in the business domain. The important role of Wageningen UR was shown by its central position in global research collaboration in the fields of plant breeding and biotechnology. Several publications of researchers on social networks (Freeman, 1980; Gould, 1987; Lee, 2010; Newman, 2010) have shown that such a prominent position positively affects innovation, because an organization with such a dominant role is able to receive and control scientific information globally. It shows that Wageningen UR plays a central role in the worldwide flow of scientific knowledge in this field.

Our analysis of developments over the past decades shows that the organization of the knowledge flow between the business domain and the research & education domain was re-organized in a specific way. It developed from a more linear knowledge flow in the triptych of Research, Education and Extension to the integrated model of Public-Private-Partnerships (PPPs). This intense collaboration between the public and private sector stimulates a continuous knowledge exchange between these two domains, and is one of the key factors in innovation of the vegetable breeding industry in the Netherlands. Moreover, this collaboration is enabled and stimulated via the intermediate organizations, which are well organized and play an active role in this industry. They not only provide a platform to link different stakeholders, they also improve communication, and stimulate co-operation and co-innovation. Some of these organizations also act as brokers between the industry and governmental institutions at the national, European and world levels.

The worldwide increase in market demand for and trends towards healthy food provides great opportunities for this breeding industry that works at supplying the basic foods that support healthy and tasty diets. Because most Dutch vegetable breeding companies are already operating internationally, they are very well positioned to anticipate the increasing demands for yields and quality, and are pushed into developing new products to respond to this demand.

Collaboration and knowledge exchange find their basis in the so-called Dutch “polder culture”. This culture is not easy to transplant to other regions, but it may still be an inspiration for other countries, regions or industries. It represents the way institutional conditions, such as regulations and legislation, are organized, and innovative formats of collaboration are supported and encouraged by the SIS. Dutch stakeholders are pro-active in this field. For example, having access to genetic variation is crucial for further innovation in breeding, but the granting of patent rights on plants and plant traits conflicts with plant breeders’ rights, in particular the breeders’ exemption (Dons and Louwaars, 2009). The Dutch branch organization Plantum initiated a worldwide debate on balancing both IP systems to assure access to genetic variation that forms the basis for innovative plant breeding.

It has shown that a well-developed and interactive SIS of the vegetable breeding industry in the Netherlands provides the conditions and innovation climate needed to create a well-performing industrial cluster in the Netherlands. This industry acquires the two key elements of geographical proximity and interconnectivity of Porter’s cluster model (Hulsink and Dons, 2008). Although the vegetable breeding industry in the Netherlands is highly consolidated with only a few main players, competition in this industry is intense. This is an indication of competitive pressure that is typical of geographically concentrated clusters. Most VBCs, research institutes, plant biotechnology companies, equipment suppliers, processors, and customers are all located in the Netherlands within 100 km of each other. There are intense interactions between different stakeholders, including public-private partnerships, close links to research and education, and strong cooperation in the supply chain. These interactions are especially stimulated by intermediate organizations and a favourable knowledge flow infrastructure, such as a collaboration culture and a well-functioning intellectual property protection system.

3.5 Conclusions and policy implications

The sectoral innovation system (SIS) of the vegetable breeding industry in the

Netherlands is characterized by an intensive knowledge flow among the different domains, which is based on innovation-driven companies, outstanding research and education institutes, strong support from active intermediate organizations, and most importantly, intensive cooperation among different stakeholders. This explains the leading innovation position of the vegetable breeding industry in the Netherlands from a systematic point of view and underlines Porter's finding that the agro-food sector in the Netherlands has a long history of "cluster approach" with an intense interaction between agro-food research and agro-food industry (Porter, 2001). This research further explains why it is critical to understand the linkages among actors involved in innovation and the interaction between the propriety and external knowledge stocks of stakeholders in the system (Bosch et al., 1999).

The SIS framework provides an integrated approach to analysing the innovation of specific industries from a systematic point of view. It helps policy makers and other stakeholders in the industry to understand the advantages and disadvantages of innovation positions and conditions in different domains of SIS: industry, research & education, intermediate organizations, market demand, and infrastructure & framework conditions. A lesson to be learnt from the innovative vegetable breeding industry in the Netherlands is how important it is to stimulate the knowledge flow between the different domains. This needs various stakeholders to understand the benefits of collaboration and how to organize collaboration in a diversity of formats. Such collaborations should be supported by an excellent institutional infrastructure for research and education and conditions that stimulate the creation of public-private partnerships, enhance intellectual property protection, encourage innovation investments, and emphasize innovation in the industry.

4. The innovation network and absorptive capacity in vegetable breeding companies in China[4]

4.1 Introduction

China accounts for 42% of the world's vegetable harvested area and 52% of the world's vegetable production. Despite annual improvements, the vegetable yield in China is still approximately one third lower than the average of Western Europe and Northern America (FAO, 2012). This is partially due to a lower innovation level of the vegetable industry in China. Closing this gap is a challenge, and also provides opportunities for vegetable breeding companies (VBCs) to develop new innovative cultivars to improve vegetable production. The vegetable breeding industry in China is an interesting case to study innovation, not only because of its enormous scale, but also because this industry is experiencing a radical reform from a planned economy to a market economy. In the present study, it focus on the role of the internal and external innovation network, as well as the role of the absorptive capacity to improve innovation and business performance of VBCs in China.

Innovation networks are assumed to be critical for a company's performance (Camagni, 1991), because a company's network of relationships constitutes a valuable source of both knowledge and resources that companies can use to pursue their interests (Miotti and Sachwald, 2003; Salman and Saives, 2005; Mohannak, 2007). This, so called social capital, is just as important as financial and human forms of capital to sustain a company's value-creation processes (Yli-Renko et al., 2002; Molina-Morales and Martínez-Fernández, 2010; Maurer et al., 2011; Laursen et al., 2012). The external innovation network includes the contacts and collaborations with external innovation partners, such as supply chain partners, universities and research institutes, intermediate organizations, consultants, governmental organizations, and even competitors. The internal innovation network consists of the interactions among the functional units of the company. Empirical studies have revealed that the innovation network of a company can

[4] This chapter is based on Zhen Liu, Ron G.M. Kemp, Maarten A. Jongsma, Caicheng Huang, J.J.M. (Hans) Dons and S.W.F (Onno) Omta. The combined effects of innovation network and absorptive capacity on innovation and business performance in vegetable breeding companies in China, submitted to Asia Pacific Journal of Management.

have a positive effect on innovation through getting access to outside knowledge, coupling of innovation resources, applying new knowledge and reducing innovation risks (Freeman, 1991; Rodan and Galunic, 2004; Batterink, 2009; Freel and de Jong, 2009; Oke and Idiagbon-Oke, 2010; Zeng et al., 2010).

However, companies cannot rely on their innovation networks alone, they also have to apply knowledge (Matthyssens et al., 2005). Knowledge is not freely available and often of a tacit nature, highly context-specific. So companies have to acquire certain capabilities to use this knowledge (Lazaric et al., 2008; Schmidt, 2010). Proposed initially by Cohen and Levinthal (1990), and further defined by Pavitt (2002) and Daghfous (2004), absorptive capacity is the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends. Zahra and George (2002) indicated the difference between potential and realized absorptive capacity. Potential absorptive capacity refers to knowledge acquisition and assimilation, capturing efforts to identify and acquire new knowledge and to assimilate this knowledge. Realized absorptive capacity refers to knowledge transformation and exploitation, giving rise to new insights by combining existing and newly acquired knowledge, and incorporating this transformed knowledge into innovations.

The large increase in studies on innovation networks and absorptive capacity shows that these are both considered to play an important role in a company's innovation performance. However, few studies have investigated the combined effect of the innovation network and absorptive capacity. In this study, a multi-dimensional measurement of potential and realized absorptive capacity were constructed that empirically validates the theoretical contribution from Zahra and George (2002). The measurements of internal and external innovation networks were also added, thereby extending the study of Camisón and Forés (2010), which only empirically studied absorptive capacity.

This chapter is based on empirical research using both quantitative and qualitative methods. A survey questionnaire, combined with semi-structured one-hour interviews, was used to obtain information from senior managers of vegetable breeding companies in China. The paper is organized as follows. In section 4.2, the theoretical model and the research hypotheses are introduced. Then, in Section 4.3, the research context of the vegetable breeding industry in China is introduced, and methods of data collection are described. In Section 4.4, the results are presented based on PLS modelling. In the endingly Section 4.5, the findings, conclusions and managerial recommendations are presented.

4.2 Conceptual model and research hypotheses

There has been a continuous stream of publications based on the innovation input-throughput-output model (Omta et al., 1994; Brouwer and Kleinknecht, 1999 ; Keizer et al., 2002; Lööf and Heshmati, 2002; Kemp et al., 2003; Luuk and Theo, 2004; Fortuin et al., 2007; Heckl and Moormann, 2010; Schwarz et al., 2012). This model is based on the three stages of the innovation process. Firstly, companies have to make decisions on the relevance of innovation for their business performance, and organize the innovation input (financial, human and knowledge resources) in order to implement an innovation strategy. The innovation throughput stage includes the process of assimilation of new (external) information and its application to develop new products. The third stage represents the generated innovation output in the form of new products and processes, which will further determine the company's competitive strength and business performance. This conceptual model is presented in Figure 4.1.

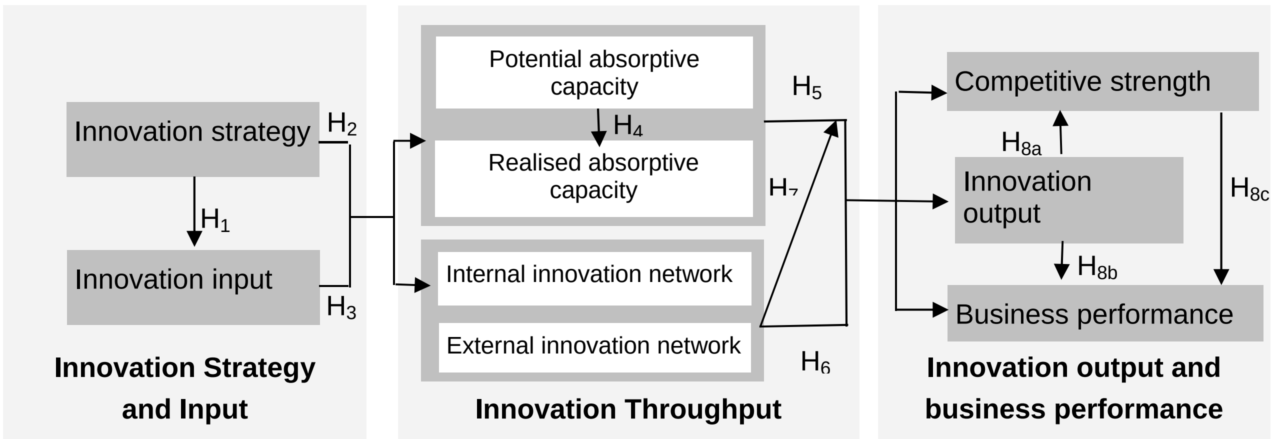


Figure 4.1 Conceptual model

The innovation strategy is the sum of strategic choices that a firm makes in terms of new product and market development plans (Strecker, 2009). It should be based on clear innovation objectives embedded in a company's strategy, and backed by senior management (Dougherty and Cohen, 1995). The innovation strategy can be regarded as a timed sequence of internally consistent resource allocation decisions that are designed to fulfil the company's objectives. A company with a strategy that is directed towards innovation is expected to have a higher innovation input by putting more resources into R&D, providing a higher R&D budget and employing more R&D personnel to stimulate innovation. Furthermore, the innovation strategy is regarded as a dynamic instrument that shapes and guides innovation in the organization (Adams et al., 2006), through providing a platform to build a company's absorptive capacity and innovation network. Thus, it arrives at the following hypotheses:

Hypothesis 1: *A strategy dedicated to innovation will be positively related to innovation input.*

Hypothesis 2: *A strategy dedicated to innovation will be positively related to the internal and external innovation network and the absorptive capacity of the company.*

With a higher innovation input, a company can accumulate knowledge and gain experience. The company's prior knowledge, accumulated by continuous R&D investments and preserved in the experience of qualified personnel, will potentially affect its ability to acquire and utilize external knowledge (Cohen and Levinthal, 1990). Furthermore, when companies have a higher innovation input, they can use more resources to collaborate with external partners, from which they can acquire external knowledge to achieve their innovation targets. This leads to the following hypothesis:

Hypothesis 3: *Innovation input will be positively related to the potential and realized absorptive capacity and the internal and external innovation network.*

Numerous theoretical and empirical studies have analysed a company's capacity to absorb knowledge, but most of them only use proxy variables as indicators for absorptive capacity, such as R&D expenditures (Scott, 2003; De Jong and Freel, 2010), number of patents (Nicholls-Nixon and Woo, 2003; Scott, 2003), number of publications (Mangematin and Nesta, 1999), and number of employees with higher education qualification (Caloghirou et al., 2004b). However, these one-dimensional measures are insufficient to capture the richness of such a complex construct as absorptive capacity (Camisón and Forés, 2010). Zahra and George (2002) link the construct to a set of organization routines and strategic processes through which companies acquire, assimilate, transfer and apply knowledge in order to create a dynamic organization. Based on the work of Kogut and Zander (1992), Lane and Lubatkin (1998), Van Den Bosch (1999), and Zahra and George (2002), Camisón and Forés (2010), it can be defined: 1) the *acquisition capacity* as a company's ability to locate, identify, value and acquire external knowledge that is critical to its operation; 2) the *assimilation capacity* as a company's ability to absorb external knowledge; 3) the *transformation capacity* as a company's capacity to develop and refine the internal routines that facilitate the transformation and to combine previous knowledge with the newly acquired and assimilated knowledge; and 4) the *application capacity* as a company's ability to build the acquired, assimilated and transformed knowledge into the operation routine and create new operations, goods and organizational forms. These four dimensions are classified into two components: *potential absorptive capacity* (acquisition and assimilation), and *realized absorptive capacity* (transformation and application). A company with a better absorptive capacity may gain a better innovation output, as it will be easier to acquire, assimilate, transform and apply knowledge to arrive at innovative products. Furthermore, potential absorptive capacity will positively affect the competitive strength through increased flexibility and through the development of new resources and capacities, while realized absorptive capacity can help to develop new products and processes, which would further improve the business performance (Zahra and George, 2002). This leads to the following hypotheses:

Hypothesis 4: Potential absorptive capacity will be positively related to realized absorptive capacity.

Hypothesis 5: Potential and realized absorptive capacity will be positively related to innovation output, competitive strength and business performance.

A company's functional units, e.g. R&D, production, distribution, and marketing and sales are embedded in a network coordinated through processes of knowledge transfer and resource sharing (Burack and Negandhi, 1977; Galbraith, 1977). Inter-functional networks are important for innovation, where a company discovers new opportunities and obtains new knowledge through interaction among its functional units. The innovation capacity of a functional unit can be significantly increased by its centrality in the intra-organizational network, which provides opportunities for shared learning, knowledge transfer and information exchange (Tsai, 2001; Ibarra et al., 2005). Furthermore, companies are embedded in networks of relationships with a heterogeneous array of economic agents: suppliers, customers, competitors, private and public research institutes and regional agencies (Freeman, 1991; Tsai, 2001). These innovation links with external partners provide a platform to access outside sources of knowledge, couple innovation resources, break through technical barriers, stimulate technology improvements, and reduce innovation risks, which are often critical to innovation (Cohen and Levinthal, 1990; Rodan and Galunic, 2004; Freel and de Jong, 2009; Classen et al., 2012). Furthermore, a company with a large external innovation network is expected to gain external knowledge more easily and therefore can seize market opportunities quicker. As a result, a larger innovation network will be beneficial to the business performance (Marques, Gerry, Covelo, Braga, & Braga, 2011; W. Tsai, 2001). This leads to the following hypothesis:

Hypothesis 6: A well-functioning internal and external innovation network will be positively related to innovation output, competitive strength and business performance.

Furthermore, inter-organizational networks, combined with intra-organizational networks in which the R&D functional unit has a central position, can be rewarding for companies so as to gain access to knowledge, to facilitate learning processes, and to foster knowledge creation (Cross and Cummings, 2004; Jansen et al., 2005; Bosch et al., 2011). The extensiveness of the external innovation network will help to increase the positive effects of a higher potential absorptive capacity on innovation output, because it extends the scope and access to knowledge. This leads to the following hypothesis:

Hypothesis 7: The extensiveness of the external innovation network will have a positive mediating effect on the relationship between absorptive capacity and innovation output.

A strong innovation output, in terms of a high innovation level, faster product development, and higher R&D returns, is highly valued by innovative companies for its positive relationship with competitive strength and business performance. From the American Management Association (AMA) survey among 1,396 top executives in large multinational companies, it was concluded that more than 90% agree that innovation is important for their company's long-term survival, with over 95% considering that this will still be the case in ten years time (Jamrog, 2006). Furthermore, competitive strength, referring to the quality of a company's products, customer relationships, flexibility of market response, delivery, etc., will also lead to a better business performance. This leads to the following hypothesis:

Hypothesis 8: The innovation output will be positively related to competitive strength (H_{8a}) and business performance (H_{8b}), and the competitive strength will be positive related to business performance (H_{8c}).

4.3 Research context and methodology

4.3.1 The vegetable breeding industry in China

The Chinese seed market, second after that of the USA (ISF, 2011a), has been experiencing a transformation from a centrally controlled industry into an open and active market since the enforcement of the new Seed Law in 2000 (Huang et al., 2001b). Recently, the threshold for participation in the seed industry has been increased based on the Guiding Opinions on Accelerating the Development of the Modern Crop Seed Industry, released by the State Council in April 2011, and its enforcement regulation - the Crop Seeds Production & Operation Licensing Rules (MoA, 2010). At the end of 2010, there were over 8,700 licensed seed companies in China, but most of them were seed producers, processers, or trading companies. When the thresholds for taking part in the seed industry were raised by these new regulations, the number of seed companies decreased to less than 6,500 in March 2013 (MoA, 2013). But there are only about 200 integrated breeding companies (active in breeding, seed production and sales), which are operating nation-wide (MoA, 2010). It is estimated that 112 vegetable breeding companies (VBCs) could meet the following three criteria: the company should be active in breeding, seed production and sales, have a focus on vegetables, and have more than 10 employees (Liu et al., 2012c). The VBCs can be divided into three groups: 1) public VBCs, which are the so-called state-owned companies, often originating from vegetable research institutes; 2) domestic private VBCs; and 3) foreign private VBCs, including wholly owned subsidiaries and joint ventures. The public VBCs have been in a leading and monopoly position in the seed industry in China for a long time. Most state-owned companies went bankrupt or were privatized after 2000 (Tong 2010), whereas vegetable research institutes were encouraged by the government to separate their research and commercial activities, though some are still active in commercializing their cultivars. The number of private VBCs has increased rapidly since 2000, often founded by plant breeders from research institutes or company employees. The large market opportunities and economic reform in China also attracted foreign VBCs (Liu et al., 2012c).

4.3.2 Sample and data collection

For the present study, I focused on the VBCs that are active in innovation. In 2009, an in-depth case study of three VBCs (one company per VBC type) for pre-testing purposes was conducted. It is asked senior managers to complete a questionnaire prior to an in-depth semi-structured interview. Based on their comments, the questionnaire was improved. In 2010 and 2011, 70 of the 112 VBCs were visited and interviewed. These 70 VBCs are located in ten provinces and in three municipalities that are directly under central government (Beijing, Shanghai, and Tianjin). These are the primary regions for vegetable production and the major locations for VBCs in China (Figure 2.2).

The senior manager's opinion about different aspects of innovation was asked using a semi-structured interview and a questionnaire with 60 closed questions, using a 7-point Likert scale. In the interviews and the questionnaire, the following six aspects were discussed: 1) the history and current organization of the company, 2) the company's business environment, 3) the company's innovation strategy and input, 4) the company's innovation network, 5) the absorptive capacity of the company, and 6) the company's innovation and business performance. In total, I collected questionnaires of 54 companies; three questionnaires were discarded due to incompleteness. Based on Slovin's formula (Pagoso et al., 1992), this sample of 51 was adequate to represent the population of 112 VBCs.

4.3.3 Construct measurement and data analysis

Most answers to the questions (items) were operationalized with Likert scales between 1 (“strongly disagree”) and 7 (“strongly agree”), except the items concerning innovation input that were measured numerically and items concerning the external innovation network that were measured categorically. The detailed items used to measure each construct are listed in Table 4.1.

For the innovation strategy and input stage, innovation strategy was measured as the strategic emphasis on innovation and innovation input in terms of the percentage of R&D investments compared to total turnover, number of the research activities, and the number of R&D employees.

For innovation throughput, the internal and external innovation network as well as the potential and the realized absorptive capacity were measured. The internal innovation network was measured in terms of the central position of the R&D unit, as well as the communication between the R&D and the other functional units of the company. The external innovation network was measured by the number of innovation partners such as suppliers, customers, competitors, research institutes, governmental agencies, associations and consultants (Freeman, 1991; Tsai, 2009). Potential absorptive capacity was measured in terms of knowledge acquisition and assimilation, such as levels of openness to the market (Lane and Lubatkin, 1998; Caloghirou et al., 2004b; Jansen et al., 2005; Soo et al., 2007) and R&D cooperation (Zahra and George, 2002; Caloghirou et al., 2004b; Arbussà and Coenders, 2007; Liao et al., 2007); human resources (Caloghirou et al., 2004b; Hayton and Zahra, 2005; Tu et al., 2006; Liao et al., 2007), and training (Caloghirou et al., 2004b; Jansen et al., 2005; Soo et al., 2007). Realized absorptive capacity was measured in terms of knowledge transformation and application, such as cross-functional collaboration and organizational arrangements that stimulate knowledge application (Mangematin and Nesta, 1999; Tsai and Wu, 2011).

Innovation output refers to the interviewees’ assessment of their companies’ innovativeness in breeding, the market entry of new products (cultivars) and the return on investments in R&D. Competitive strength was measured by aspects of the creation of new goods (cultivars) and services and aspects related to a reduction of costs (Bonanno and Haworth, 1998; Akgün et al., 2009; Capitanio et al., 2010). Business performance was measured in terms of growth, profit margin and market position.

The answers given in the questionnaire on all different items were analysed using SPSS and Partial Least Squares (Wold, 1980). Firstly, an exploratory factor analysis with oblique rotation was used to select the most relevant items for all the constructs (Table 4.1). Then factor loading, composite reliability, and average variance extracted were obtained for each measurement separately and for the structural model as a whole.

Wold's (1980) Partial Least Squares (PLS) model was employed, because the sample size of this research was limited (51), due to the small population of vegetable breeding companies. PLS path modeling can avoid small sample size problems, and can therefore be applied in situations where other methods (e.g. LISREL) cannot be used (Götz et al., 2010). The requirement of adequate sample size of PLS path modeling is ten times the largest number of structural paths directed at a particular construct in the inner path model (Chin and Newsted, 1999). The model in this study complies with this requirement in this study. PLS modeling also has less stringent assumptions about the distribution of variables and error terms. Furthermore, PLS path modeling can estimate complex models with many latent and manifest variables, and it can also handle both reflective and formative measurements (Henseler et al., 2009). For this analysis, the SmartPLS 2.0 software developed by Ringle, Wende, & Will (2005) was used.

In PLS, bootstrapping is a resampling procedure used to examine the stability of estimates for each parameter in the PLS model. Resamples of the observed dataset were obtained by sampling with replacement from the original data set. The bootstrap procedure utilizes a confidence estimation procedure other than the normal approximation (Efron and Tibshirani, 1993). This procedure produces t-statistics, which helped us to judge whether the proposed relationships were significant or not. Following Chin (1998), I ran a 500 resampling bootstrap.

4.4 Results

4.4.1 Reliability and validity of constructs

The individual item reliability (factor loading), internal consistency (composite reliability) and discriminant validity for each construct were examined using the criteria from Fornell & Larcker (1981). The item reliability is provided in Table 4.1 and the internal consistency and discriminant validity of the constructs is provided in Table 4.2.

Factor loadings of most individual items are higher or close to 0.7 (Table 4.1), which shows a good reliability of the individual items. Some items show a factor loading a bit less than the cut-off of 0.7 (0.6 or higher) but still indicating an acceptable individual reliability (Götz et al., 2010). The composite reliability (CR) for all constructs exceeds 0.75 (Table 4.2), indicating a robust internal consistency of the constructs (Hair et al., 2011).

The discriminant validity was exmained in two ways. First, the square root of the average variance extracted should be greater than all construct correlations. Second, all items should load higher to their associated construct than to the other constructs. Both criteria for discriminant validity were met (Table 4.2).

Table 4.1 Measurement and factor loadings for each construct of the model

Construct	Items	Mean	S.D.	Factor loading
	Innovation Strategy and Input			
Innovation strategy	Innovation is important to our company in maintaining competitiveness	6.78	0.55	0.91
	Our firm fights the competition by aiming for market dominance	5.90	1.20	0.90
Innovation input	R&D budget (% of turnover)	14.16	10.46	0.64
	Number of methods/tools that your company uses in collaboration with the most important innovation partners	14.88	16.04	0.78
	Number of R&D employees	15.18	15.53	0.88
	Innovation throughput			
Potential absorptive capacity	We monitor on a regular basis the extent to which our products and processes align to our customers' needs	5.66	1.40	0.65
	We attend exhibitions and trade fairs more frequently than our competitors	4.82	1.41	0.75
	We regard training of employees as an investment, not as a cost	5.66	1.19	0.76
	We share a common vision: once we stop learning our future will be in danger	6.03	1.28	0.80
	We consistently codify the "lessons learned" at the end of innovation projects	5.64	1.54	0.66
Realized absorptive capacity	Our company encourages employees to also know the work procedures of other than those of their own department	4.72	1.37	0.87
	Our company arranges informal activities to improve understanding among different departments	5.13	1.63	0.60
	There are many innovation teams in which different ranks of employees collaborate	4.87	1.52	0.76
Internal innovation network	The R&D department plays a central role in our company	6.53	0.73	0.85
	There is excellent communication between R&D and production	5.32	1.56	0.61
	There is excellent communication between R&D and marketing & sales	5.98	1.06	0.67
External innovation network	Number of innovation partners with our main suppliers	2.82	1.97	0.61
	Number of innovation partners with other seed companies	2.94	1.99	0.75
	Number of innovation partners with universities and research institutes	2.36	1.17	0.86
	Number of innovation partners with governmental agencies	1.97	1.31	0.9
	Number of innovation partners with associations	1.86	0.75	0.82
	Innovation output and business performance			
Innovation output	How innovative would you consider your company to be in breeding processes	4.87	1.24	0.65
	How innovative would you consider your company to be in product production and logistics	4.96	1.35	0.70
	How innovative would you consider your company to be in marketing	5.16	1.31	0.85
	How innovative would you consider your company to be in distribution	4.99	1.29	0.83
	Our new products enter the market faster compared to our main competitors' products	5.13	1.35	0.79
	The returns from R&D relative to the R&D investments are: (1) very low— (7) very high	4.93	1.48	0.62
Competitive strength	The main competitive strength(s) of our company are: quality	6.20	0.83	0.68
	The main competitive strength(s) of our company are: delivery	4.97	0.95	0.81
	The main competitive strength(s) of our company are: customer relationships	5.77	1.03	0.87
	The main competitive strength(s) of our company are: our flexibility of market response	5.48	1.25	0.79
Business performance	The market share of our first main product is growing quickly	5.42	1.29	0.81
	Compared to our main competitors, our annual growth rate is much higher	5.00	1.17	0.83
	The current position of our company compared to our main competitors can be characterized as: (1) follower—(7) leader	5.54	1.17	0.82
	Compared to our main competitors, our operating profit margin is much higher	4.96	1.07	0.68
	We expect the sales volume of our current products in the coming three years to increase rapidly	5.41	1.12	0.70

Table 4.2 Inter-correlation of constructs

	AVE	CR	AVE	1	2	3	4	5	6	7	8	9	10
1. Innovation strategy	0.82	0.90	0.82	**0.91**									
2. Innovation input	0.60	0.81	0.60	0.05	**0.77**								
3. Internal innovation network	0.53	0.85	0.53	0.26	-0.10	**0.73**							
4. External innovation network	0.56	0.79	0.56	0.10	-0.19	.381**	**0.75**						
5. Potential absorptive capacity	0.51	0.76	0.51	0.42**	0.06	0.15	0.08	**0.71**					
6. Realized absorptive capacity	0.63	0.89	0.63	0.04	0.49**	-0.06	-0.14	0.07	**0.79**				
7. Potential absorptive capacity * external innovation network	0.53	0.98	0.53	-0.02	-0.07	-0.01	0.00	-0.09	0.01	**0.73**			
8. Innovation output	0.56	0.88	0.56	0.43**	-0.16	0.38**	0.37**	0.14	-0.04	0.21	**0.75**		
9. Competitive strength	0.62	0.87	0.62	0.35*	-0.05	0.56**	0.32*	0.28*	-0.06	-0.08	0.62**	**0.79**	
10. Business performance	0.59	0.88	0.59	0.53**	0.09	0.30*	0.30*	0.40**	0.12	-0.01	0.69**	0.64**	**0.77**

*Correlation is significant at 0.05 level (2-tailed)
**Correlation is significant at 0.01 level (2-tailed).
[a] The bold numbers on the diagonal are the square roots of the variance shared by the constructs and their measures (square root of average variance extracted, referred to as AVE). CR refers to the composite reliability and off-diagonal are the correlations among the constructs.
[b] all items within the constructs were measured by 7-point Likert scales except the innovation input and the external network.

Table 4.3 Path coefficients, t-values, significant level and effect size of structural model

	Path Coefficients[1]	T-value (β)	f^2-value[2]
Innovation input (R^2=0.00)			
Innovation strategy	0.05	0.44	0.00
Potential absorptive capacity (R^2=0.12)			
Innovation strategy	0.32**	2.36	0.13
Innovation input	-0.13	0.83	0.02
Realized absorptive capacity (R^2=0.18)			
Innovation strategy	0.01	0.08	0.00
innovation input	-0.15	1.01	0.02
Potential absorptive capacity	0.36**	2.25	0.16
Internal innovation network (R^2=0.24)			
Innovation strategy	0.48***	2.68	0.32
innovation input	0.07	0.5	0.01
External innovation network (R^2=0.29)			
Innovation strategy	0.04	0.29	0.00
innovation input	0.54***	3.4	0.37
Innovation output (R^2=0.35)			
Potential absorptive capacity	0.32**	2.42	0.22
Realized absorptive capacity	0.30*	1.77	0.09
Internal innovation network	0.11	0.96	0.02
External innovation network	0.00	0.57	0.09
Potential absorptive capacity* External innovation network	0.27*	1.78	0.09
Competitive strength (R^2=0.56)			
Potential absorptive capacity	0.41***	3.21	0.27
Realized absorptive capacity	0.32	0.15	0.00
Internal innovation network	0.15	1.3	0.05
Innovation output	0.44***	3.11	0.32
Business performance (R^2=0.67)			
Internal innovation network	0.27***	2.95	0.18
External innovation network	0.15	1.32	0.06
Realized absorptive capacity	0.07	0.57	0.03
Innovation output	0.48***	3.57	0.36
Competitive strength	0.26**	2.02	0.12

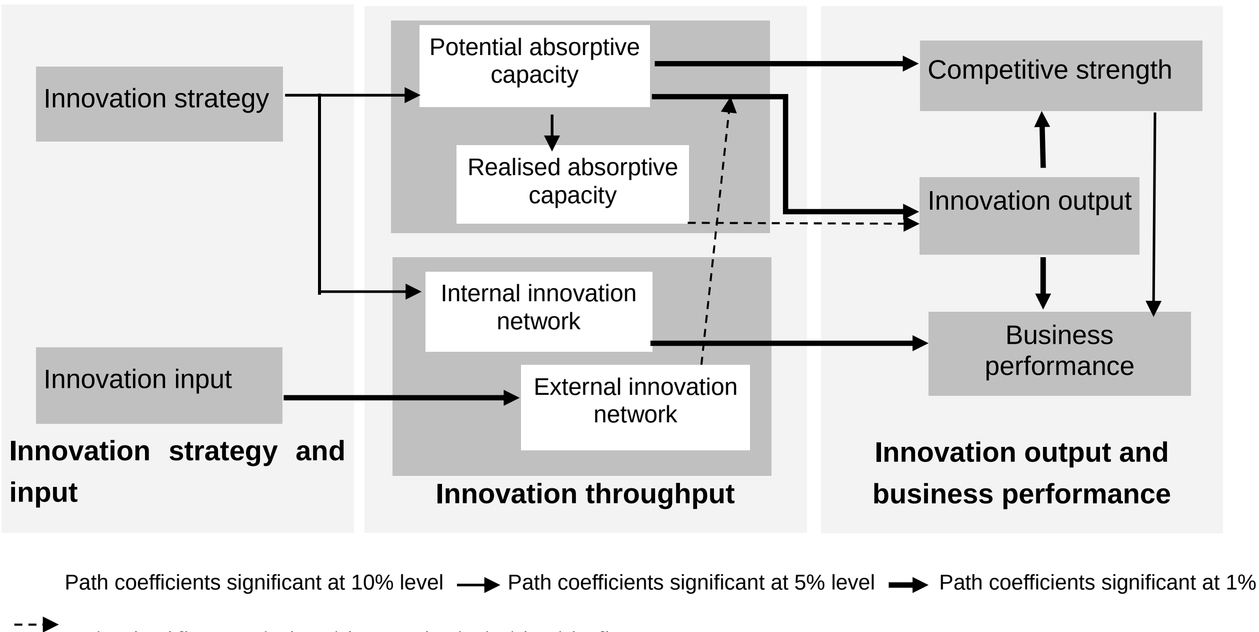
Note:
[1] * Path coefficient is significant at 0.1 level (2-tailed); ** Path coefficient is significant at 0.05 level (2-tailed); *** Path coefficient is significant at 0.01 level (2-tailed).
[2] f^2-value of 0.02, 0.15 and 0.35 can be viewed as cut-off for whether a predictor latent variable has a weak, medium or large effect at the structure level.

4.4.2 Explanatory power of constructs

The average variance explained (R^2) was used to evaluate the explanatory power of the structural model, the path coefficients, t-value and the effect size were used to evaluate the correlation of constructs, their significant level and effect size (Table 4.3). For innovation throughput: potential absorptive capacity (0.12), realized absorptive capacity (0.18), internal innovation network (0.24), and external innovation network (0.29) show an acceptable explanatory power, significant at 0.05 level (Eisenhauer, 2009). Furthermore, R^2 of innovation output (0.35), competitive strength (0.42), and business performance (0.67) indicate robust explanatory power. Moreover, the goodness of fit (GoF) is 0.64, which shows a high level of significance of the whole PLS model (Latan and Ghozali, 2012).

4.4.3 Structural model

The results of the structural model are shown in Figure 4.3 and Table 4.3.



Note: only significant relationships are included in this figure

Figure 4.3 Results of the structural model

It shows that the innovation strategy is positively related to the internal innovation network (β=0.48) and the potential absorptive capacity (β=0.32), but not to the external innovation network and realized absorptive capacity. The innovation input is positively related to the external innovation network (β=0.54). Potential absorptive capacity positively affects innovation output (β=0.32) and the competitive strength (β=0.41), while realized absorptive capacity positively affects innovation output (β=0.30), but has no direct positive effect on business performance. Furthermore, only the internal innovation network positively affects the business performance (β=0.27), whereas the external innovation network was found to have a moderating effect (β=0.27) on the relationship between potential absorptive capacity and innovation output. The innovation output is positively related to competitive strength (β=0.44) as well as to business performance (β=0.48). The detailed results are presented in Table 4.4, which shows that most hypotheses were confirmed.

It is the shared vision of the senior managers of the VBCs that innovation is very important for the competitiveness of their business (mean of innovation strategy is 6.48, with a S.D. of 0.68), but the analysis showed that innovation strategy was not positively related to innovation input. VBCs in China clearly know the importance of innovation and modestly invest in innovation (mean and median of R&D budget as % of turnover are 14.8% and 10% respectively), but they hesitate to invest heavily in R&D to accelerate innovation or by hiring more qualified R&D employees. The weak intellectual property rights protection in China could partly explain this hesitation to increase the innovation input.

Guided by their innovation strategy, VBCs make efforts to organize the company in such a way that in-house communication and collaboration are facilitated by a good internal innovation network. They also encourage employees to acquire external knowledge and develop personal competences, in order to build up absorptive capacity. For example, some larger companies are organized using a matrix structure, support job rotation, and stimulate personal competence development. Smaller companies have short internal communication channels, and some of them keep in close contact with other VBCs to exchange experiences.

The VBCs with a higher innovation input clearly choose to invest in building a larger external innovation network, rather than to further develop their absorptive capacity. These results show that acquiring knowledge and resources from external sources is more important or beneficial than accumulating knowledge by investing internally. This may be explained by the fact that many public research institutes are actively breeding new cultivars rather than conducting more basic research in breeding and germplasm improvement. Thus, it is easier for VBCs to acquire market-ready cultivars or half-products from research institutes. In cases of fast developing VBCs, many of them indicated the importance of collaboration with public research institutes or independent breeders to develop cultivars.

Contrary to the expectation, the innovation network had no significant impact on innovation output, only the external network had an intermediate effect on the relationship between potential absorptive capacity and innovation output. Moreover, the internal innovation network had a positive effect on a company's business performance. This shows that accessing external knowledge and resources is not enough for developing a better innovation output in terms of high innovation level and fast product development or for increasing competitive strength. VBCs can have better business performance if they are embedded in a well-developed external innovation network with diversity and a large number of innovation partners, especially through collaboration with research institutes. The embeddedness would help the company to access the external knowledge, which further stimulates innovation output as the company could acquire more knowledge. Having enough absorptive capacity to further develop and market the cultivars is crucial for a good innovation output, and the innovation output in turn is crucial for better business performance.

Figure 4.3 shows that potential absorptive capacity strongly affects realized absorptive capacity, because the continuing renewal of stocks of knowledge and the assimilation of this knowledge into a company's knowledge-base is the primary source of innovation. Potential absorptive capacity leads to higher competitive strength. Both potential and realized absorptive capacity lead to better innovation output, but neither significantly affects business performance directly. This means that developing absorptive capacity is not enough to gain a better business performance, so VBCs need to develop innovative products first. However, potential absorptive capacity is positively related to competitive strength, which further affects the business performance.

Both absorptive capacity and innovation network are important for innovation and business performance. It was found in the interviews that different types of companies used different strategies. The private VBCs have much less input in terms of R&D resources and capacities, compared to public and foreign companies, but they have an effective internal communication and are active in collaborating with external partners to gain new products to ensure their competitive position on the market. Furthermore, the external innovation network has a moderating effect on the relationship between potential absorptive capacity and innovation output, which aligns with the fact derived from the interviews that some newly founded but quickly developing VBCs were building up their own capacities to develop new cultivars and also using their innovation network by cooperating with research institutes.

Table 4.4 Overview of the confirmed and not confirmed hypotheses

Hypothesis 1	
A strategy dedicated to innovation will be positively related to innovation input.	Not confirmed
Hypothesis 2	
a. A strategy dedicated to innovation will be positively related to the potential absorptive capacity	Confirmed
b. A strategy dedicated to innovation will be positively related to the realised absorptive capacity.	Not confirmed
c. A strategy dedicated to innovation will be positively related to the internal innovation network.	Confirmed
d. A strategy dedicated to innovation will be positively related to the external innovation network.	Not confirmed
Hypothesis 3	
a. The innovation input will be positively related to the potential absorptive capacity.	Not confirmed
b. The innovation input will be positively related to the realised absorptive capacity.	Not confirmed
c. The innovation input will be positively related to the internal innovation network.	Not confirmed
d. The innovation input will be positively related to the external innovation network.	Confirmed
Hypothesis 4	
Potential absorptive capacity will be positively related to realized absorptive capacity.	Confirmed
Hypothesis 5	
a. Potential absorptive capacity will be positively related to innovation output.	Confirmed
b. Potential absorptive capacity will be positively related to competitive strength.	Confirmed
c. Realised absorptive capacity will be positively related to innovation output.	Confirmed
d. Realised absorptive capacity will be positively related to competitive strength	Not confirmed
e. Realised absorptive capacity will be positively related to business performance	Not confirmed
Hypothesis 6	
a. Internal innovation network will be positively related to innovation output.	Not confirmed
b. Internal innovation network will be positively related to competitive strength.	Not confirmed
c. Internal innovation network will be positively related to business performance.	Confirmed
d. External innovation network will be positively related to innovation output.	Not confirmed
e. External innovation network will be positively related to business performance	Not confirmed
Hypothesis 7	
The extensiveness of the internal and external innovation network will have a positive mediating effect on the relationship between absorptive capacity and innovation output.	Confirmed
Hypothesis 8	Confirmed
a. The innovation output will be positively related to competitive strength.	Confirmed
b. The innovation output will be positively related to business performance.	Confirmed
c. The competitive strength will be positive related to business performance.	Confirmed

4.5 Conclusions and applications

This study advances the understanding of key success factors of innovation in vegetable breeding companies in China by applying an input-throughput-output model, and by focusing on the internal and external innovation network of VBCs and their potential and realized absorptive capacity. The measurements allowed us to reveal the effect of the internal and external innovation network on innovation and business performance and enabled us to examine the process of acquisition and assimilation (potential absorptive capacity) and transformation and application (realized absorptive capacity) of external knowledge and resources for innovation.

Two main strategies were identified for VBCs to reach better innovation output and business performance. One is the innovation orientation strategy. With its innovation strategy, the company develops its absorptive capacity, which leads to better business performance via a high innovation output and a strong competitive strength. This is applied mainly by the foreign VBCs and the larger and older private VBCs. They have developed a clear innovation strategy, consistently invest in internal R&D and optimize their organizations. Another is the network orientation strategy. Here, the company achieves better innovation output by using its innovation network. The public VBCs, with high innovation input, however, have limited communication between R&D and the other functional units or innovation partners externally. However, I recommend combining these two strategies to gain access to external knowledge and to improve the absorptive capacity to make effective use of this knowledge. The fast growing young VBCs are already starting to use this combined strategy.

The empirical study confirms that the measurement instruments meet the requirements of dimensionality, validity and reliability, and as such represent an interesting tool for further research. The results of this study, however, cannot be fully generalized because the authors collected data only from a single innovative industry, i.e. the vegetable breeding industry in China. However, the results presented could be used as an initial model to explore the influence on innovation output of the combination of absorptive capacity and innovation network in other countries and industries.

5. An absorptive capacity perspective on innovation in the vegetable breeding industry in China and the Netherlands[5]

5.1 Introduction

The vegetable breeding industry is highly recognized as an innovation-driven industry, which invests intensively in R&D. It requires large financial resources to apply innovative technologies to the development of new varieties (Dons and Bino, 2008). In the vegetable breeding sector in the Netherlands, breeding companies spend on average 19% of their turnover on R&D, with some spending more than 30% (Liu et al., 2012c). This is even more than the pharmaceutical industry spends on R&D (Cooke, 2006). Companies in the breeding industry are embedded in a competitive environment, facing continuously changing challenges such as the need to contribute to food security, develop high quality varieties, and support integrated production in a sustainable way. Therefore, their performance is increasingly dependent on the continuous improvement of breeding processes and the introduction of innovative products (new varieties).

Defined initially by Schumpeter (1934), innovation is a process of creative destruction, in which the quest for profits pushes companies to innovate constantly, breaking old rules to establish new ones. However, innovation is also costly, time-consuming and uncertain. For example, Cooper and Edgett (2009) found that 44% of all innovation projects fail to achieve their profit target, only one out of seven product concepts becomes a new product winner and half of all new product launches are late to market. Since the basic work of Cooper (1979), numerous empirical studies have been conducted in order to disclose the key success factors of innovation projects. There are several different streams of studies, focusing on factors that are related to planning and execution proficiency of the innovation process (Cooper, 1978; Cooper and Kleinschmidt, 1987; Johne and Snelson, 1988; Hinrichsen et al., 2004), focusing on in-depth aspects such as information-processing (Cooper, 1999; Lievens and Moenaert, 2000; Fortuin et al., 2007; Aramburu and Saenz, 2010; Oke and Idiagbon-Oke, 2010) and focusing on a

[5] This chapter is based on Zhen Liu, Ron G.M. Kemp, Maarten A. Jongsma, Caicheng Huang, J.J.M. (Hans) Dons and S.W.F (Onno) Omta. An absorptive capacity perspective on innovation in the Dutch and Chinese vegetable breeding industry, submitted to the 23rd Annual World Forum and Symposium of International Food and Agribusiness Management Association.

resource-based view of innovation projects (Balachandra and Friar, 1997; Belout and Gauvreau, 2004; Blindenbach-Driessen and van den Ende, 2006; Lu and Yuan, 2010). Based on these studies, Tepic (2012) divided the factors that influence innovation performance into three categories: 1) innovation-related factors, i.e. project novelty and newness to the company; 2) organisational capabilities, including functional capabilities that are related to specific knowledge of the different functional units of the company, e.g. R&D, manufacturing, marketing, distribution, sales and financing, etc., and integrative capabilities that refer to communication, team interaction, knowledge sharing; and 3) innovation potential (i.e. product and market potential).

Proposed initially by Cohen and Levinthal (1990), and further defined by Pavitt (2002) and Daghfous (2004), absorptive capacity is the ability of a company to first recognize the value of new, external information, then to assimilate it, and finally apply it to commercial ends. Lane and Lubatkin (1998), Zahra and George (2002), and Camisón and Forés (2010) further identified four dimensions of absorptive capacity: acquisition, assimilation, transformation and application capabilities. The substantial increase in studies on absorptive capacity shows that absorptive capacity is considered to play an important role in a company's overall innovation performance. However, few studies have investigated the role of absorptive capacity at the level of innovation projects within a company. In this study, the concept of absorptive capacity was used in an analysis of R&D projects in the vegetable seed companies by exploring the factors that affect the innovation process and performance of such projects.

This chapter is organized as follows. In Section 5.2, the conceptual model and research hypotheses are introduced. In Section 5.3, the research context and methodology of the vegetable seed industry in China and the Netherlands is described, as well as how was the data collected and analysed. Then, in the Section 5.4, the results based on PLS modelling are presented, and those are discussed in Section 5.5 with general conclusions and managerial recommendations.

5.2 Conceptual model and research hypotheses

A conceptual model was proposed (Figure 5.1) based on the three categories of factors which affect innovation project performance (Tepic, 2012): innovation related factors (product novelty, newness to the company), organisational capabilities (team communication, cross-functional communication, functional capabilities) and innovation potential (market and product potential). These factors are integrated in the four dimensions of absorptive capacity (acquisition, assimilation, transformation and application) to understand the dynamics of innovation processes. In these four dimensions, new, external information is acquired, assimilated, transformed and applied to commercial products or services. In the acquisition stage, communication is the basis for acquiring external information and identifying new opportunities. Then, in the assimilation stage, innovation projects are initiated to analyse, process, interpret and understand the information obtained from external sources. In the transformation stage, the project team needs the functional capabilities of the other functional units within the company to facilitate and combine existing knowledge with the newly acquired and assimilated knowledge. Finally, based on the knowledge acquired in the earlier stages, combined with knowledge about the market, the company will be able to translate the newly acquired knowledge to new products, with a high market potential in the application stage. Together with external influences such as competition, the potential of the developed products will ultimately determine the innovation project performance.

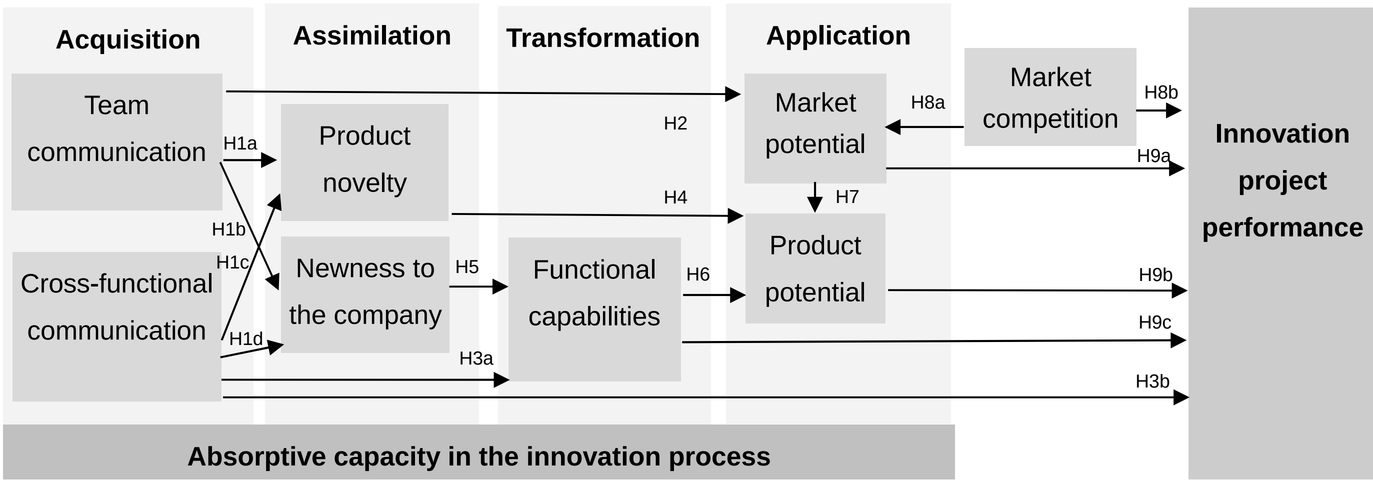


Figure 5.1 Conceptual model

Below, the hypotheses of our conceptual model are described in more detail.

Novelty is highly emphasised as important by many researchers in studies on innovation (Amara et al., 2008; Therrien et al., 2011). However, ways of determining the value of new products stem from existing knowledge that often creates barriers to innovation (Carlile and Lakhani, 2011). Communication is recognized as important in overcoming such barriers, because it creates clarity and understanding of the value of new knowledge. Communication is also important for teams to acquire a shared comprehensive and understanding of complex, inter-related activities. Previous research about new product development showed that the qualities of communication, team interaction, and knowledge sharing have a positive effect on the innovation process (Kivimaki et al., 2000; Moenaert et al., 2000; Aramburu and Saenz, 2010; Kyriazis et al., 2012; Liu et al., 2012a). There are two kinds of communication: one is team communication, which refers to the communication among innovation project team members. Another is cross-functional communication, which refers to the communication between the innovation project team and the other functional units in the company and the collection of information from outside the company. The openness of communication, which is defined as the degree to which team members are willing to exchange their ideas and knowledge within the innovation project team, as well as with the functional units within the company, plays an important role in knowledge implementation (Lin, 2011). The openness to acquire internal and external information and exchange information with team members and other functional units will help to identify the most advanced technology and latest market trends, and then implement and develop this knowledge in innovation projects. Cross-functional communication can help the company to develop its functional capabilities to support product development (Lievens and Moenaert, 2000; Lawson et al., 2009; Kyriazis et al., 2012). Cross-functional communication has been identified as a key driver of new product success, by helping to build and maintain a productive interface between the functional units. It assures that integration takes place among the separate capabilities delivered by engineering, production, and marketing departments (Pinto and Pinto, 1990; Griffin and Hauser, 1992; Thamhain, 2003; Sarin and O'Connor, 2009). This leads to the following hypotheses:

Hypothesis 1: Team and cross-functional communication will be positively related to product novelty and to newness to the company.

Hypothesis 2: Team communication will be positively related to identifying the market potential of an innovation.

Hypothesis 3: Cross-functional communication will be positively related to the development of the functional capabilities (H3a) and ultimately to innovation project performance (H3b).

Innovative projects usually need the application of advanced technology to solve complex problems and offer solutions to customers that existing products are not able to offer. The degree of novelty is likely to affect the dynamics of disclosure and the speed of new product development (Rindova and Petkova, 2007), and would entail a less open discussion with competitors (Cooper, 1978; Oakey and Cooper, 1991). Furthermore, advanced innovative technologies are not easy for adopters to imitate, because they need to invest heavily to accumulate relevant knowledge and technologies to develop similar products. The more novel the innovation project is, the greater the opportunities for the company to develop outstanding products to meet potential market demand (Im and Workman Jr, 2004). The support of a company's different functional capabilities is indispensable to develop successful commercial products. It is the key to acquire insight into the specific needs of the customer during the design phase, and subsequently to develop adequate production, marketing and sales skills to successfully launch the new product to the market (Cooper and Kleinschmidt, 1987). However, there is a trade-off. Cooper (1979) found the innovation projects' newness to the company to be negatively related to innovation project success, because this requires new engineering skills, new distribution channels and dealing with new customers and competitors. So, new areas of activities might lead to difficulties and uncertainties in adjusting current functional capabilities to these new requirements. This leads to the following hypotheses:

Hypothesis 4: Product novelty will be positively related to product potential.

Hypothesis 5: Newness to the company will be negatively related to the company's existing functional capabilities.

Hypothesis 6: Functional capabilities of the company will be positively related to product potential.

Strong market demands will also prolong the lifetime of new products (Mahajan et al., 1979; Im and Workman Jr, 2004; Tepic, 2012). Clear understanding of the market demands will help the project team to develop innovative products with a high market potential. Highly competitive environments may bring greater uncertainty to an innovation project, as competitors may launch similar products on the market earlier or with a lower price, which could affect innovation performance negatively (Mikkola, 2001). However, with the support of the company's improved functional capabilities, the project team may achieve better innovation project performance in terms of better products, shorter development time and less cost etc. This leads to the following hypotheses:

Hypothesis 7: Market potential will be positively related to product potential.

Hypothesis 8: Market competition will be negatively related to market potential (H8a) and to innovation project performance (H8b).

Hypothesis 9: Market potential (H9a), product potential (H9b) and functional capabilities (H9c) will all be positively related to innovation project performance.

5.3 Research context and methodology

5.3.1 The vegetable breeding industry in China and the Netherlands

Companies in the Netherlands enjoy positions as global market leaders of plant reproduction material (seeds of grasses and vegetables, seedlings, cuttings, seed potatoes, and flower bulbs). The Netherlands accounts for about one third of the world's vegetable seed exports and one eighth of the world's vegetable seed imports (Plantum, 2012). This outstanding position is based on craftsmanship, entrepreneurship and innovation, making the vegetable seed industry in the Netherlands the most innovative in the world (LEI, 2012). Due to mergers and acquisitions over the past three decades, the vegetable seed industry has become much more consolidated. More than 85% of the vegetable seed market in the world was acquired by the top ten vegetable seed companies, which mostly originated or have important R&D stations in the Netherlands (Liu et al., 2012b). The vegetable seed sector in the Netherlands is also highly consolidated with only 28 active companies. Among those, only 10 can be categorized as vegetable breeding companies (VBCs) that are active in breeding new cultivars, production and sales of vegetable seeds, and with a reasonable size (> 10 employees). All other companies are either smaller or only active in production and sales of seeds. These VBCs are either private family-owned companies or part of large multinationals (Table 3.1).

The Chinese seed market, in size second after that of the USA (ISF, 2012), is fast growing but also experiencing a radical reform from a planned to a market economy. Unlike the consolidated seed industry in the Netherlands, the seed industry in China is very fragmented with over 8,700 seed companies at the end of 2010 (MoA, 2013). This number was reduced to less than 6,500 seed companies in March 2013 (MoA, 2013), because the thresholds for taking part in the seed industry were raised by new regulations (MoA, 2010). Most of the seed companies are seed producers, processors, or trading companies. It was estimated that there were only 112 VBCs active in the vegetable breeding industry in China (Liu et al., 2012c). Those VBCs can be divided into three groups: 1) public VBCs, which are the so-called state-owned companies, often spin-offs from research institutes; 2) domestic private VBCs; and 3) foreign private VBCs, including wholly foreign owned subsidiaries and joint ventures between foreign companies and Chinese companies.

5.3.2 Sample and data collection

For the present study, I focused only on VBCs that are active in innovation and are continuously working on the development of new vegetable cultivars. In 2009, an in-depth case study of two VBCs in the Netherlands and three VBCs in China were conducted for pre-testing purposes. Project managers were asked to complete a questionnaire prior to an in-depth semi-structured interview. Based on their comments, I improved the questionnaire. In 2010 and 2011, I collected 68 valid questionnaires from 44 VBCs (8 in the Netherlands and 36 in China). In some of the large companies, which have large numbers of innovation projects, managers were asked to fill out more than one questionnaire. In China, information on 52 projects, and in the Netherlands on 16 projects, was collected.

In each of the companies, the managing director or R&D director were interviewed about their organization, their innovation strategy, and innovation and business performance. Then one or more project managers/researchers in charge of the innovation projects were asked to fill out the questionnaire, while keeping a specific research project in mind. About 70% of the respondents were researchers, another 20% held positions in production or management, and the rest held marketing and sales functions.

Table 5.1 Distribution of respondents according to their experience in the breeding industry, current company and position

	1-5 years (%)	**6-10 years** (%)	**11-15 years** (%)	**16-20 years** (%)	**>20 years** (%)	**Median of respondents of companies in China**	**Median of respondents of companies in the Netherlands**
Years in the industry	26.5	20.6	14.7	17.6	20.6	10.0	19.0
Years in the company	42.6	17.7	15.2	14.7	8.8	8.0	18.0
Years in current position	54.4	20.1	11.8	4.4	5.9	5.0	7.0

The distribution of respondents according to their experience is provided in Table 5.1. It shows that around 50% of the respondents had already worked for more than 5 years in the company and also in that position. About three quarters of the respondents had worked more than five years in the seed industry, whereas the remaining one quarter consists mainly of young employees. Of the respondents with over five years of experience, nearly 80% stayed in the same companies and over 60% kept the same position. So, in general, the respondents within the sample had quite some experience in their innovation projects and companies. Furthermore, respondents in the Netherlands in general have longer experience in the seed industry, in their company and their position.

5.3.3 Construct measurement and data analysis

For each innovation project a questionnaire was collected. The questionnaire contained 58 ten-point Likert scale questions about the perceptions of the respondents on a number of important issues (constructs). These were: team communication, cross-functional communication, product novelty, project newness to the company, functional capabilities, product and market potential, market competition and innovation project performance. The respondents were asked to indicate to what extent they completely disagreed (1) or completely agreed (10) with the statements. The questionnaire was built using the NewProd innovation assessment tool (Cooper, 1979), and combined with questions about the communication capabilities of the innovation team, as developed by Hollander (2002) in Genesis (a follow-up to NewProd) and Wageningen Innovation Assessment Toolkit (WIAT) (Im and Workman Jr, 2004; Fortuin et al., 2007; Batterink, 2009).

SPSS was used to select the most relevant items for all constructs by applying exploratory factor analysis with oblique rotation. Then 39 items were identified as valid to measure those described constructs (Table 5.2). As the sample size was relatively small (68), due to the small population of vegetable breeding companies in China and the Netherlands, Wold's (1980) Partial Least Squares (PLS) model was used to test the conceptual model and the nine hypotheses. PLS path modeling can avoid small sample size problems, and can, therefore, be applied in situations where other methods (e.g. LISREL) cannot be used (Götz et al., 2010). Besides the less strict requirement of sample size, the PLS path modeling has also several advantages over covariance structure analysis and is generally preferred when: 1) requirements of multivariate normality and interval scaled data cannot definitely be met; 2) the primary concern of the analysis lies in the prediction accuracy when estimating a complex model with many variables and parameters; 3) the observations are not truly independent from each other; or 4) the model contains formative indicators (Sarstedt, 2008; Henseler et al., 2009). For this analysis, the SmartPLS 2.0 software developed by Ringle et al. (2005) was used. Then factor loadings (item reliability), composite reliability, and average variance extracted (AVE) were obtained for each measurement separately, and for the structural model as a whole. Following Chin (1998), I ran a 500 resampling bootstrap with replacement. In PLS, bootstrapping is a resampling procedure used to examine the stability of estimates for each parameter in the PLS model. The bootstrap procedure utilizes a confidence estimation procedure other than the normal approximation (Efron and Tibshirani, 1993), which helped us to judge whether the proposed relationships were significant or not.

5.4 Results

In this section, the relationships among the factors that might affect the performance and success of an innovation project will be analysed. As discussed in Section 3.1, the vegetable seed industries in China and the Netherlands are quite different from each other. However, among all innovation projects that have been analysed only limited differences were found after comparing the innovation projects in both countries. That means that it was possible, at the abstract level that can be used in the present study, to combine the data of the VBCs in China and the Netherlands.

5.4.1 Reliability and validity of constructs

The individual item reliability (factor loading), internal consistency (composite reliability) and discriminant validity for each construct were examined by using the criteria given by Fornell and Larcker (1981). Factor loadings of most individual items were higher than 0.7 (Table 5.3), which shows a good reliability of the individual items. Two items showed a factor loading a bit less than the cut-off point of 0.7 (0.61 and 0.65) but still indicating an acceptable individual reliability (Götz et al., 2010). The composite reliability (CR) for all constructs exceeded 0.8 (see Table 5.3), indicating a robust internal consistency of the constructs (Hair et al., 2011).

The discriminant validity was addressed in two ways. First, the square root of the average variance extracted (AVE) should be greater than all construct correlations. Second, all items should load higher to their associated construct than to the other constructs. Both criteria for discriminant validity were met (see Table 5.4). The path coefficients, t-value and the average variance explained (R^2) of each endogenous variables are presented in Table 6. It gives a visual overview of the relations among the constructs. R^2 was used to evaluate the explanatory power of the structural model. R^2 for product novelty (0.12), newness to the company (0.09), functional capabilities (0.22), market potential (0.20), product potential (0.57), and innovation project performance (0.47) are accepted for explanatory power significance at the 0.05 level (Eisenhauer, 2009).

Table 5.2 Measurement and factor loadings for each construct of the model

Construct	Items	Mean	S.D.	Factor loading
Team communication	1. I have enough communication with my team members to do my work efficiently and in an effective way.	7.82	1.48	0.83
	2. In this project, I am the one who most frequently requires information and support from the other team members.	7.75	2.00	0.87
	3. In this project, I am the one who most frequently provides information and support to other team members.	7.57	1.85	0.60
Cross-functional communication	4. We always give other departments (e.g. M&S, manufacturing, etc.) the information they ask for.	8.52	1.42	0.77
	5. We always get the information from other departments (e.g. M&S, manufacturing, etc.) we ask for.	8.06	1.59	0.87
	6. All our team members are focused on "collecting" knowledge for our project.	7.78	1.71	0.83
Product novelty	7. The product type is totally new for our company (e.g. new crops, etc.).	6.67	2.50	0.73
	8. We have never made or sold products to satisfy this type of customers need or use before (e.g. new disease-resistant, new shape, etc.).	6.93	2.16	0.74
	9. The potential customers for this product are totally new for the company (e.g. new area, new type of customers, etc.).	4.96	2.63	0.77
	10. The technology required to develop this product is totally new to our company.	5.47	2.66	0.71
	11. The competitors we face in the market for this product are totally new to our company.	4.54	2.51	0.71
Newness to the company	12. The nature of the production process is totally new for our company.	4.78	2.42	0.61
	13. The distribution system and/or type of sales-force for this product is totally new to our company.	5.00	2.50	0.88
	14. The type of advertising and promotion required is totally new to our company.	4.91	2.45	0.89
Functional capabilities	15. Our engineering skills and people are more than adequate for this project.	6.41	2.33	0.83
	16. Our marketing research skills and people are more than adequate for this project.	6.29	2.06	0.87
	17. Our advertising and promotion resources and skills are more than adequate for this project.	6.28	2.08	0.82
	18. Our sales and/or distribution resources and skills are more than adequate for this project.	6.22	2.18	0.91
Market potential	19. The market for this product is growing very quickly.	6.94	2.02	0.85
	20. Potential customers have a great need for this type of product.	7.41	1.65	0.79
	21. The customer will definitely use the product.	6.76	1.75	0.64
	22. This product has a high potential (i.e. can additional products, multiple styles, price ranges).	7.60	1.43	0.79
	23. This project will contribute to the competitive advantage of the company.	8.21	1.24	0.75
	24. This new product will surely meet the applicable laws (e.g. product liability, regulations, and product standards).	8.65	1.31	0.65
Product potential	25. Our product will be of higher quality than competing products.	7.22	1.97	0.79
	26. Compared to competitive products, our product will offer a number of unique features or attributes to the customer.	7.60	1.84	0.83
	27. Our product will permit the customer to do a job or do something he/she cannot presently do with what is available.	6.88	2.15	0.88
	28. Our product will permit the customers to reduce their overall costs, when compared to what they use now.	6.87	2.04	0.70
	29. Our product is highly innovative totally new to the market.	6.44	1.96	0.79
	30. Our product is a very high technology one.	6.31	2.12	0.72
	31. Our product is mechanically and/or technically very complex.	6.16	2.24	0.80
Market competition	32. The market is a highly competitive one.	8.38	1.54	0.93
	33. There are many competitors in this market.	8.06	2.22	0.95
Innovation project performance	34. What is the probability that this project will be completed within the original planning?	7.37	1.97	0.87
	35. What is the probability that this project will be completed within the original budget?	7.35	1.60	0.87
	36. What is the probability that this project fulfils all its objectives?	7.68	1.49	0.88
	37. What is the probability that this project will directly benefit the end-users (either through increasing efficiency or effectiveness)?	7.97	1.33	0.72
	38. What is the probability that this project will earn more money for the company than it costs?	7.96	1.65	0.80
	39. What is the probability that this project will improve customers' loyalty to the company?	7.85	1.57	0.73

Note: all items were measured by ten-point Likert scale that respondents completely disagreed (1) or completely agreed (10) of the statements.

Table 5.3 Discriminant validity of constructs

	Mean	S.D.	AVE	CR	1	2	3	4	5	6	7	8	9
1.Team communication	7.72	1.35	0.60	0.81	**0.77**								
2.Cross-functional communication	8.13	1.30	0.68	0.86	0.49**	**0.82**							
3.Product novelty	5.77	1.82	0.54	0.85	0.33**	0.07	**0.73**						
4.Newness to the company	4.91	2.02	0.65	0.84	.028*	0.13	0.50**	**0.81**					
5.Functional capabilities	6.30	1.85	0.73	0.92	0.18	0.245*	0.15	0.39**	**0.85**				
6.Market potential	7.67	1.15	0.56	0.88	0.46**	0.25*	0.38**	0.08	0.21	**0.75**			
7.Product potential	6.82	1.61	0.62	0.92	0.22	0.03	0.55**	00.37**	0.36**	0.65**	**0.79**		
8.Market competition	8.25	1.71	0.88	0.94	0.40**	0.56**	0.04	-0.05	0.21	0.23	-0.04	**0.94**	
9.Innovation performance	7.70	1.30	0.66	0.92	0.50**	0.44**	0.13	0.00	0.13	0.50**	0.35**	0.50**	**0.81**

Note:
*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed).
[a] The bold numbers on the diagonal are the square roots of the variance shared between the constructs and their measures (square root of average variance extracted, AVE). CR refers to composite reliability and Off-diagonal are the correlations among the constructs.
[b]all the constructs measured by ten-point Likert scale indicators

5.4.2 Explanatory power of constructs

Table 5.4 Path coefficients, t-values and significant level of structural model

	Path Coefficients (β)[1]	**T-value**	**f2-value[2]**
Product novelty (R^2=0.12)			
Team communication	0.39***	3.01	0.13
Cross-functional communication	-0.11	0.68	0.01
Newness to the company (R^2=0.09)			
Team communication	0.31**	2.20	0.08
Cross-functional communication	-0.02	0.13	0.00
Functional capabilities(R^2=0.22)			
Cross-functional communication	0.25**	2.07	0.08
Newness to the company	0.37***	2.77	0.28
Market potential(R^2=0.20)			
Team communication	0.42***	3.22	0.18
Product potential(R^2=0.57)			
Market potential	0.47***	4.61	0.42
Product novelty	0.33***	3.17	0.20
Functional capabilities	0.21**	2.46	0.09
Innovation project performance(R^2=0.47)			
Market potential	0.23	1.16	0.05
Cross-functional communication	0.23**	2.30	0.06
Product potential	0.36**	2.03	0.06
Functional capabilities	-0.15	1.37	0.04
Market competition	0.36*	1.93	0.13

[1] * Path coefficient is significant at 0.1 level (2-tailed); ** Path coefficient is significant at 0.05 level (2-tailed); *** Path coefficient is significant at 0.01 level (2-tailed).
[2]f^2-value of 0.02, 0.15 and 0.35 can be viewed as gague for whether a predictor latent variable has a week, medium or large effect at the structure level.

The average variance explained (R^2) was used to evaluate the explanatory power of the structural model, the path coefficients, t-value and the effect size were used to evaluate the correlation of constructs, their significant level and effect size (Table 6). For product novelty (0.12), newness to the company (0.09), functional capabilities(0.22) and market potential(0.20) show an acceptable explanatory power significant at t 0.05 level (Eisenhauer, 2009). Furthermore, R^2 of product potential (0.57) and innovation project performance (0.47) indicate robust explanatory power. Moreover, the goodness of fit (GoF) is 0.51, which shows a high level of significance of the whole PLS model (Latan and Ghozali, 2012).

5.4.3 Structural model

The results of the structural model are provided in Figure 5.2 and Table 5.4. Below the result of confirmed, unconfirmed and rejected hypotheses were described in more detail (Table 5.5).

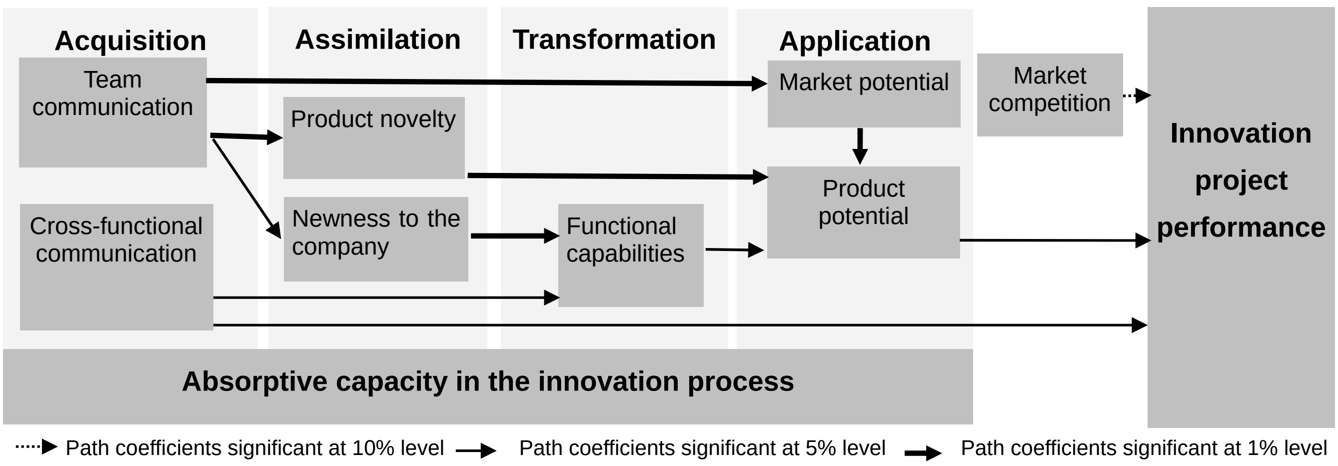


Figure 5.2 Results of the structural model

As expected, at the acquisition stage, a significant positive relationship was found between team communication and product novelty (β=0.39) as well as newness to the company (β=0.31), while no significant relationship was found between cross-functional communication and product novelty and newness to the company. This shows that in the acquisition stage of innovation projects of VBCs it is essential to have a good communication between project team members concerning the acquired information, the identification of new opportunities, and the implementation of such information into the innovation projects that targeted novelty products and newness to the company. Moreover, it was also found that team communication is positively related to market potential (β=0.42). This shows that holding intensive discussions within the project team helps to understand the potential for the project on the basis of the acquired information.

At the stage of assimilation it was found that product novelty is highly positively related to product potential (β=0.33). This was expected since product novelty leads to the development of products that are unique and/or cost efficient than competing products. However, in contrast to the expectations the newness to the company had a positive rather than a negative effect on functional capabilities (β=0.37). Assimilation capability refers to the company's routines and processes that allow it to analyse, process, interpret and understand the information obtained from external sources (Zahra and George, 2002). The result might indicate that the main requirement at the assimilation stage of an innovation project is to adjust the internal routines and processes to meet the challenges of the project's newness to the company. This indicates that the greater the newness of the innovation project in the vegetable seed sector, the more efforts are put into adjusting and stimulating the functional skills, routines and processes to support the innovation project.

At the stage of transformation, cross-functional communication plays an important role. The functional capabilities are positively related to product potential (β=0.21). Good cross-functional communication that communication between the innovation project team and the other functional units, such as production, marketing and sales, will help the company to develop or adjust relevant functional capabilities to support the innovation project in developing, marketing and selling a new product to potential new customers. Without access to all relevant skills in the company, such as engineering, marketing, and sales, it is difficult to develop a unique product of high quality that will appeal to customers. However, the functional capabilities have no direct effect on innovation project performance.

At the application stage, project novelty is converted into product potential. As expected, market potential (β=0.47) is positively related to product potential. The effect size of market potential (f^2=0.42) on product potential is much larger than effect of product novelty (f^2=0.20) and functional capabilities (f^2=0.09) on product. This indicates that identifying the market potential of the innovation projects in the breeding industry is more important than developing very novel products or developing new functional capabilities for introducing new products to the market.

Finally, it was found that market potential has no direct effect on innovation project performance, but as expected, market potential is positively related to product potential (β=0.47), which in turn is positively related to innovation project performance (β=0.36). So the market potential is only indirectly related to innovation project performance. Market and product potential together have a large effect (f^2=0.35) on innovation project performance. Furthermore, market competition has a positive effect on innovation project performance, which indicates that intensive competition can help innovation projects to achieve a better performance, because it stimulates both the team members and the company as a whole to really come up with an innovative product in time.

Table 5.5 Overview of the confirmed, unconfirmed and rejected hypotheses

Hypothesis 1	
a. Team communication will be positively related to product novelty	Confirmed
b. Team communication will be positively related to newness to the company.	Confirmed
c. Cross-functional communication will be positively related to product	Not confirmed
d. Cross-functional communication will be positively related to newness to the company.	Not confirmed
Hypotheses 2	
Team communication will be positively related to identifying the market potential of an innovation.	Confirmed
Hypotheses 3	
a. Cross-functional communication will be positively related to the development of the functional capabilities	Confirmed
b. Cross-functional communication will be positively related to innovation project performance	Confirmed
Hypotheses 4	
Product novelty will be positively related to product potential.	Confirmed
Hypotheses 5	
Newness to the company will be negatively related to the company's existing functional capabilities.	Rejected
Hypotheses 6	
Functional capabilities of the company will be positively related to product potential.	Confirmed
Hypotheses 7	
Market potential will be positively related to product potential	Confirmed
Hypotheses 8	
a. Market competition will be negatively related to market potential.	Not confirmed
b. Market competition will be negatively related to innovation project performance.	Rejected
Hypotheses 9	
a. Market potential will be positively related to the innovation project performance.	Not confirmed
b. Product potential will be positively related to the innovation project performance.	Confirmed
c. Functional capabilities will be positively related to the innovation project performance.	Not confirmed

5.5 Conclusions and applications

The present study on innovation projects supports the results of Markose (2004), Hall (2005), Amara et al. (2008), and Therrien et al. (2011), that product novelty is highly important for innovation, while communication is recognized as being important to overcome the barriers of novelty. In the present study on innovation projects in the vegetable breeding industry, two kinds of communication and their roles at different stages of the innovation process were identified. One is team communication among the innovation project team members, which plays an important role in the acquisition and assimilation of information and the conception of new ideas for innovation projects. The exchange of information and interactions between individuals of the project team can produce new ideas through brainstorming and identifying new opportunities. The other kind of communication is cross-functional communication between the innovation project team and other functional units of the company. Good cross-functional communication makes the innovation project team aware of the existing capabilities of the different functional units that they can use, while the functional units get informed about the probably missing skills, routines and processes that are needed to support the innovation product when it is launched onto the market. A good understanding of these missing requirements might be the starting point for adjustment and improvement.

It was expected that the newness to the company would be negatively related to existing functional capabilities, because innovations, which are complex and new to the company, generally are more challenging to the existing functional capabilities. The result of this study is also different from the findings of Cooper (1979) and Tepic (2012). They found that the newness of the innovation project was negatively related to the functional capabilities, because a company needs a higher level of flexibility and adaption when it engages in a completely new innovation. The deviation in results of this study may be related to the specific context of innovation in vegetable breeding companies (VBCs), which in most of the cases includes the development of novel varieties, a time-consuming process which normally takes up to 10 years or even longer. As indicated in the interviews with company employees, cross-functional teams are widely used for innovation projects. Researchers, breeders, business developers, etc. work closely together at different stages of product development, maintaining good communication within the project team, and also with the other functional units. In such a long period of product development, the companies gradually develop the functional capabilities needed to support innovation. Moreover, such new projects encourage companies to improve their functional capabilities. In contrast to this, the study of Tepic (2012) concerned nine large multinational companies, which might lead to long communication channels and a slow adoption of relevant new functional capabilities. Furthermore, it was found that "newness to the company" of the innovation projects scored lower than 5 on a ten-point Likert scale. This could mean that the production process, distribution, advertising and promotion for the innovation projects of the VBCs are in general not totally new, so the requirements for flexibility and adaption of functional capabilities for innovation projects are not too radical.

Another unexpected result is that market competition was positively related to innovation project performance. Market competition indeed will stimulate the innovation project performance because such competition urges companies to come up faster with unique new products. This form of "healthy tension" or "good competition" was mentioned by several CEOs of outstanding breeding companies as a stimulus for innovation. These CEOs cherished and respected their competitors, although they represented a huge challenge to them, especially among the vegetable breeding companies in the Netherlands.

6 Discussion and conclusions

In the present thesis, the impact of the innovation network and the absorptive capacity of the vegetable breeding industry in China and the Netherlands were studied at sector, company and project level. Taking a knowledge-based view, different approaches were used to gain insight into the various aspects of the innovation process to obtain a more complete picture of innovation. At the sector level, the sectoral innovation system (SIS) approach was applied to study factors that affect innovation, by analysing the role and interactions of the main actors in different domains in the sector. At the company level, the internal and external innovation network and the potential and realized absorptive capacity were measured to determine their effects on innovation and business performance. At the project level, the interaction between integrative and functional capabilities and their effects on innovation project performance were examined, using the four dimensions of absorptive capacity (acquisition, assimilation, transformation and application).

In this final chapter, the main results and conclusions of the present research are summarized in Section 6.1. The theoretical and methodological contributions are presented in Section 6.2, and the limitations of the study and directions for further research are discussed in Section 6.3. The policy and managerial implications are introduced in Section 6.4 with specific recommendations on how to achieve better innovation, business and project performance.

6.1 Main results and conclusions

The overall objective of the present study was to identify the key success factors for innovation and business performance, using empirical studies of vegetable breeding companies in China and the Netherlands. To achieve this, two research questions (RQs) were proposed in the Chapters 2 and 3 (RQ1) and in Chapter 4 and in Chapter 5 (RQ2).

Research Question 1 (RQ1): what are the main drivers and barriers for an effective and well-functioning sectoral innovation system in the cases of China (Chapter 2) and the Netherlands (Chapter 3)?

To answer this research question, the sectoral innovation system (SIS) approach was adopted to examine the main actors of different domains and the interactions among them in the vegetable breeding industries in China and the Netherlands. This approach is based on the premise that understanding the linkages among the various actors involved in innovation processes is key to understanding innovation performance. The SIS was analysed with a focus on the knowledge flow, because knowledge and learning are key determinants of innovation (Malerba, 2002) and the interaction between internal and external knowledge stocks is important for innovation performance (Cohen and Levinthal, 1990). As described extensively in Chapter 2, the SIS framework includes the main actors in the 1) business, 2) research & education, and 3) intermediate organization domains, where the main actors are located, and allows explanation of the interactions in terms of knowledge stock and knowledge flow, and the societal setting in terms of 4) market demand and 5) infrastructure and framework conditions, such as policies and regulations, and trust and norms. These five domains together can provide a complete overview of the innovation mechanisms at the sector level.

Table 6.1 Comparison of the sectoral innovation system of the vegetable breeding industry in China and the Netherlands

Domains	China	The Netherlands
1.Business	• Fragmented with more than one hundred small breeding companies • Both private and public companies • High R&D investments based on subsidies	• Consolidated with ten big and specialized small breeding companies • Only private companies • High R&D investments
2.Research & education	• Intensively encouraged and invested in by government • Limited cooperation	• Both investments from government and the private sector • Both domestic and international collaboration
3.Intermediate organizations	• Fast increasing investments in public extension systems • Limited intermediate organizations, only dedicated to marketing, not to research	• Extensive public-private partnerships • Diversified intermediate organizations both for marketing and research
4.Market demand	• Large domestic market	• Large international market
5.Infrastructure & framework	• Improving, but still poor intellectual property protection • Favourable regulations for encouraging innovation especially in the breeding companies	• Pioneer in developing regulation to encourage and protect innovation • Collaboration culture
Knowledge stock and flow	• Knowledge stock is increasing due to high R&D investments in research and education by the government and gradually increasing investments by the industry. • Knowledge flow is constrained due to poor intellectual property protection, limited intermediate organizations, and dominant role of government organizations providing low incentives to collaborate.	• Knowledge stock is high and increasing both in the business and research & education domains by extensive investments from both the government and industry in private-public partnerships. • Knowledge flow is encouraged both domestically and internationally by diversified collaborations among the different domains. The SIS acquired a leading international research collaboration position.

The study in Chapter 2 led to the conclusion that a lack of interaction and knowledge flow between different domains constrains innovation in the vegetable breeding industry in China, while the study in Chapter 3 leads to the conclusion that the excellent innovation level of the vegetable breeding industry in the Netherlands is not only based on an outstanding performance in each domain of the SIS, but also on good interactions between different domains. So both studies in China and in the Netherlands point to the importance of interaction between the different domains for innovation in the sector. Table 6.1 summarizes the differences and similarities of the different SIS domains of the vegetable breeding industry in China and the Netherlands, and provides insight into the basis of the knowledge stocks and flows in these two countries.

The breeding industry is a strategically important sector with a strong potential for stimulating the economy, and, as a result, innovation is heavily emphasized in both countries. However, the approaches to stimulating innovation are quite different. In the vegetable breeding industry in China, it was found that the government plays multiple roles with public organizations being active as important actors in all three relevant domains: business, research & education and intermediates. The government not only runs the agricultural research institutes and universities, but also the larger companies and agricultural extension organizations. The heavy governmental investments have discouraged investments from private companies. With low R&D investments in the business domain the absorptive capacity to acquire, assimilate, transform and apply new scientific and technological knowledge may be low as well, as prior knowledge based on proprietary R&D activities is a prerequisite for a high level of absorptive capacity within a company. Furthermore, in the research & education domain, the research institutes are not organized efficiently enough to enable the high investments needed for modern biotechnology. Chinese public organizations in the vegetable breeding industry (public VBCs, research & education organizations, intermediate organizations) are not motivated to collaborate, as they compete with each other for the same government budget. Indeed, very few successful examples of R&D collaborations between public organizations and private industry were found, despite the fact that collaboration was highly stimulated by several national programs. This appears to be due to the fact that no incentive was given to public organizations to collaborate with private rather than with public companies. Due to the mixed interests, private companies tend to be regarded as direct competitors, either for selling seeds or for obtaining governmental financial support. As a result, there are very few intermediate organizations that aim to stimulate and facilitate collaborations in R&D. This constrained innovation network leads to limited knowledge flow between and within the different domains. However, it is a positive development that more and more employees in both the business and research & education domains are graduating or are being educated at foreign universities and research institutes, which allows them to access knowledge from international networks. Besides, many large international VBCs are activate in the Chinese vegetable seed market, and apart from the competition they raise, they have also brought their knowledge and expertise to China. This potentially extends the scope of knowledge within the SIS of the vegetable breeding industry in China.

In contrast to the situation in China, the actors in the different domains of the SIS of the vegetable breeding industry in the Netherlands are specialized within their domain and intensively collaborate with actors in the other domains. The government plays a supportive role to encourage different actors to innovate in their own domains by favourable policies, such as tax reduction on R&D investments for breeding companies. More importantly, the government stimulates initiatives to build collaboration platforms of actors across domains, but does not itself act in multiple domains. The focus of governmental funding for research has completely shifted to basic and strategic research and all applied research of direct use for companies is only subsidized if it holds a sufficient dimension of strategic interest. For strategic research, with joint public and industry interest, public-private partnerships are organized. In commercial and applied research, the companies themselves are active with large R&D investments. The activities of the different domains have helped to build their absorptive capacity based on knowledge gained from prior R&D investments, while innovation networks are organized to facilitate the knowledge flow between different domains. Furthermore, the actors in the Netherlands both in the business and research & education domains are actively involved in international collaboration. VBCs have a global distribution of R&D, production, and sales units, and research & education organizations are embedded in extensive international collaboration networks. The knowledge flow is stimulated by these international networks, which further expands the knowledge boundaries of the SIS.

Thus, in answer to RQ 1, it can conclude that for an effective and well-functioning SIS both in China and the Netherlands, the drivers and barriers are the following.

1. The drivers: Specialization of actors within their domains and collaboration with actors across different domains. Specialization stimulates actors in each domain to focus on what they are best at, and build absorptive capacity from these investments. However, innovation cannot develop in isolation. Companies need to acquire knowledge externally. Thus, innovation networks are needed to initiate collaboration and access external knowledge. Furthermore, (international) market demand and favourable institutions also encourage knowledge flow between the different domains, which provide external drivers and internal support for innovation.

2. The barriers: Constrained knowledge flows. The knowledge flow efficiency directly affects the performance of any SIS: it has made the vegetable breeding industry in the Netherlands outstanding in the world, while it can be shown that a lack of such efficiency is causing the vegetable breeding industry in China to lag behind. The key factor limiting absorptive capacity and innovation network development in China is the blurry division

of actors' roles in the different domains, which discourages specialization and collaboration. Furthermore, the infrastructure and framework conditions of the vegetable breeding SIS, such as weak intellectual property protection and heavy subsidies for research institutes, discourage VBCs from investing in internal R&D and external collaborations. As a result they also fail to attract individual talents that can carry and execute such knowledge flow.

Research Question 2 (RQ2): what is the role of the innovation network and the absorptive capacity on a company's innovation and business performance at the company (Chapter 4) and project (Chapter 5) level.

Company level

To answer RQ2 the input-throughput-output model of innovation processes was first applied at the company level, first. There are three stages of the innovation process according to the input-throughput-output model. Firstly, companies make decisions on the relevance of innovation for their business performance and organize the innovation input (financial, human and knowledge resources) to allow implementation of the innovation strategy. Secondly, at the innovation throughput stage, companies develop both internal and external innovation networks by close collaboration of departments within the company and with external partners, such as suppliers, buyers, competitors and research institutes, or work to improve the organization for better absorptive capacity to acquire, assimilate, transform and apply external knowledge. Thirdly, at the innovation output stage, based on the absorptive capacity and knowledge gained from the innovation network, new products can be developed and competitive strength can be gained, which will further determine the company's business performance.

As found in the previous chapters, although innovation is considered highly relevant for their business by VBCs both in China and the Netherlands, it is quite differently organized in the two countries, and the empirical data also show this difference between these two countries. It is not possible, therefore, to integrate the data collected from these two countries. Moreover, the number of VBCs in the Netherlands is very small (10), so that, even with a complete dataset, it did not generate a sample size large enough to test the model separately. For this reason, the research model used to answer RQ2 at the company level was based on the data from VBCs in China alone. Partial least squares (PLS) modelling was used to test the research model and proposed relationships in the research model. The major findings are summarized here within the context of the vegetable breeding industry in China.

Our results show that in China acquiring knowledge and resources externally is more important or beneficial to VBCs than accumulating knowledge by investing internally. Many public research institutes are actively breeding new cultivars rather than conducting more basic research in breeding and germplasm improvement. Thus, it is much more cost-effective for private VBCs to acquire market-ready cultivars or half-products from research institutes than to develop these themselves. It was shown that the external network had a positive intermediate effect on the relationship between potential absorptive capacity and innovation output. This shows that VBCs can gain extra benefits if they have a large external innovation network, which stimulates innovation when they use it to acquire and assimilate knowledge.

Two main strategies were identified for VBCs in China to improve their business performance, one based on absorptive capacity and one based on the innovation network. With an absorptive capacity strategy, the company builds up a strong internal R&D unit. This strategy is used mainly by the foreign VBCs and the larger and older private VBCs in China. They have developed a clear innovation strategy, consistently investing in R&D. With an innovation network strategy, the company achieves better business performance by using its internal and external network of relationships. This works well for private VBCs, but the public VBCs show limited communication between R&D and the other internal functional units or with external innovation partners. It recommends combining these two strategies to gain access to external knowledge and to improve the absorptive capacity to make effective use of this knowledge. It is already found that especially the fast growing young VBCs in China are using this combined strategy.

The roles played by innovation network and absorptive capacity in the innovation and business performance of individual VBC companies in China can therefore be summarized as follows:

- The innovation network allows VBCs to gain access to potentially valuable knowledge and resources both internally and externally. The internal innovation network positively affects business performance, if the R&D units gain a central position in the company and have good communication with the other functional units. The external innovation network can stimulate the effect of potential absorptive capacity on innovation output, as it can extend access to external knowledge.

- Potential and realized absorptive capacity are both positively related to innovation output, but neither significantly affects business performance directly. This means that developing absorptive capacity is not enough to gain a better business performance.

- Companies can gain better business performance by either an innovation network or an absorptive capacity strategy. However, the optimal strategy is to combine these two strategies to gain access to external knowledge and to improve the absorptive capacity to make effective use of this knowledge.

Project level

In order to answer RQ2 at the project level, the innovation process of VBCs in both countries were evaluate. It is distinguished the following stages needed to acquire, assimilate, transform and apply internal and external knowledge into commercial products, aligned to the four dimensions of absorptive capacity. The partial least squares (PLS) modelling was applied to test the research model and proposed relationships presented in Chapter 5. The major findings are summarized below.

The innovation process is a continuous process with different contributions from each of the four stages:

- During the acquisition stage, it is essential to have a good communication between the project team members to discuss the acquired information, to identify new opportunities, and to implement this information in new innovation projects.
- During the assimilation stage, acquired external and integrated internal knowledge are assimilated into new projects. Product novelty can improve the product potential, but the newness to the company requires the company to adjust its internal routines and processes to meet the challenges of the project's newness to the company.
- During the transformation stage, cross-functional communication plays an important role. Good communication between the innovation project team and the other functional units, such as production, marketing and sales, will help the company to develop or adjust its relevant functional capabilities to develop, market and sell the new product to customers.
- During the application stage, novel products have to be introduced to the market, so identifying the market potential of the new products is essential in this stage.

The study in Chapter 5 leads to the conclusion that communication plays an essential role in an innovation project to overcome the barriers of novelty. In the present study, two kinds of communication and their roles at different stages of the innovation process were identified. One was team communication that plays an important role in acquiring and assimilating information to get novel ideas for innovation projects, and the other was cross-functional communication between the innovation project team and the different functional units. Through extensive discussions, the functional units get informed about missing functional skills, routines and processes to support the innovation product before it is launched onto the market.

Furthermore, we found that project newness to the company was positively related to the functional capabilities of the company. This contradicts the findings of Cooper (1979) and Tepic (2012), who found a negative relationship. They argue that a company needs a high level of flexibility and adaption when it engages in a completely new innovation project. The deviation in results of this study may be related to the specific context of innovation in vegetable breeding companies (VBCs), which, in most of the cases, include the development of novel varieties, a time-consuming process, which normally takes up to 10 years or even longer. Cross-functional teams are commonly used in VBC innovation projects, so the researchers, breeders, business developers, etc. work closely together during the different stages of product development, maintaining good communication within the project team, and also with the other functional units. In this long period of product development, the companies gradually develop the functional capabilities that are needed to support the innovation. So the innovation process can be understood as dynamic that it is not limited in the innovation project itself, but also stimulates the other functional units to develop related functional capabilities to pursue the target of the innovation project. Then the co-development of the innovation and functional capabilities will further determine the product potential at the application stage, which is positively related to innovation project performance.

In summary, in order answer to RQ2 at the project level, it can conclude that the main factors that affect the innovation process of VBCs at the project level are the following.

- Integrative capabilities, referring to team communication and cross-functional communication between the project team and the other functional units, play an important role at the acquisition and assimilation stage of the innovation process. Team communication is especially important at the acquisition stage to acquire information and external knowledge for novel innovation projects and to identify their market potential. Cross-functional communication is also important during the assimilation stage to stimulate the other functional units to develop supportive functional capabilities for the new products.

- Functional capabilities, referring to the specialised roles of the different functional units to develop, produce and market a product, play an important role especially during the transformation and application stage of the innovation process. With the support of the functional units, the innovation project team can transform the novel ideas into new products with a high market potential.

6.2 Theoretical and methodological contributions

6.2.1 Theoretical contributions

The present study focussed on the plant breeding industry in China and the Netherlands, and the conclusions described in the previous sections, therefore, primarily apply to these specific sectors. At the same time the results of the study can be extrapolated to a more general level. The present study provides more insight into the role of innovation network (Newman, 2010; Omta and Fortuin, 2010; Schoubroeck and Kool, 2010) and absorptive capacity (Pavitt, 2002; Daghfous, 2004) which are two important parameters in understanding innovation and business performance at different levels.

Specifically, this study extends the knowledge-based perspective on innovation upward to the sector level and downward to the project level. So far, this theory was exclusively based on studies of innovation at company level (Kogut and Zander, 1996; Spender, 1996; Blindenbach-Driessen and van den Ende, 2006; Dodgson et al., 2008a; Lopez and Esteves, 2013). We used the sectoral innovation system (SIS) approach to analyse innovation at the sector level and used the absorptive capacity perspective to analyse innovation processes at the project level. Secondly, a multi-dimensional measurement of potential and realized absorptive capacity was carried out that empirically validated the theoretical contribution of Zahra and George (2002). Measurements of internal and external innovation networks were also added, thereby extending the study of Camisón and Forés (2010) that only focused on absorptive capacity, leaving the network aspect unobserved. Thirdly, I extended studies on innovation processes based on the absorptive capacity perspective at the project level (Borsi and Schubert, 2011; European Commission., 2011; ISF, 2011b; LEI, 2012; NSF, 2012), by analysing the interaction of factors in the four absorptive capacity stages (acquisition, assimilation, transformation and application) of the innovation process, in order to find the key factors that affect innovation project performance.

Innovation network

Understanding the links among all actors involved in innovation processes is key to understanding innovation performance (Freeman, 1987).

At the sectoral level, the innovation performance not only depends on how the various stakeholders in different domains perform individually, but also on how they interact with each other as elements in a collective system of knowledge creation and use, and on their interplay with social institutions. The different performances of SIS in the vegetable breeding industries in China and in the Netherlands can not only be explained by the stock of knowledge present in the various domains but also, and more importantly, by differences in the fluidity of knowledge flow and interactions between the domains.

At the company level, it was shown that the external innovation network can positively enhance the relationship between potential absorptive capacity and innovation output, because the external innovation network can help the company to access knowledge from different channels. Meanwhile, the internal innovation network directly positively affects the innovation output when the R&D teams can benefit from their central position, while supported by the other functional units with information and resources.

At the project level, the innovation networks refer to the contacts and communication of the project team members. Team communication is especially important during the acquisition stage of the innovation process, because it can help the team members to gain novel ideas for the innovation project. Cross-functional communication between the innovation project team and other functional units is especially important during the transformation stage of the innovation process. It stimulates the other functional units to develop relevant functional capabilities, which are needed for the introduction of innovative products to the market.

Absorptive capacity

In the present study, I extended the concept of absorptive capacity, so far used only in the context of a company, to the higher abstraction level of the sector, as well as to the more concrete level of the innovation project.

At the sectoral level, the degree of knowledge flow between the different domains not only depends on the amount of previously accumulated knowledge and the organization of the stakeholders in the different domains in the sector, but also on institutional aspects such as culture, trust, collaboration, regulations and policies. A nice example in this study is the so-called “polder culture” in the Netherlands. Trust, build through long-term collaboration, is certainly one of the key success factors in the vegetable breeding industry in the Netherlands. In China, on the other hand, the ineffective intellectual property protection system is having negative effects on the innovation performance of the vegetable breeding industry, as it makes the different actors more reluctant to collaborate, resulting in a restricted knowledge flow.

At the company level, it was found that neither potential nor realized absorptive capacity had a direct effect on business performance, but they both had a significant positive effect on innovation output. So it is advisable for companies to choose first to develop their absorptive capacity to gain a higher innovation level, which will then lead to better business performance.

The concept of absorptive capacity was also used to analyse the innovation process at the project level in the four stages: acquisition, assimilation, transformation and application. These four stages are interactive and dynamically affect innovation performance. Integrative capabilities, such as team communication and cross-functional communication, play an essential role in the innovation process, especially in the acquisition and transformation stage. Functional capabilities, related to the knowledge and skills of the different functional units, e.g. R&D, manufacturing, financing, marketing and sales, play an important role at the transformation and application stage. Both integrative and functional capabilities are needed to recognize the value of new, external information, assimilate it, and apply it to commercial ends.

Innovation and business performance

The main conclusion of the present study on innovation management is that, irrespective of the integration level (whether sectoral, company or project level), the key success factor is acquisition, integration and application of both internal and external knowledge into development and enhancement of products or processes. In Figure 6.1 an integrated picture of the innovation network, absorptive capacity and innovation performance at sectoral, company and project level is presented.

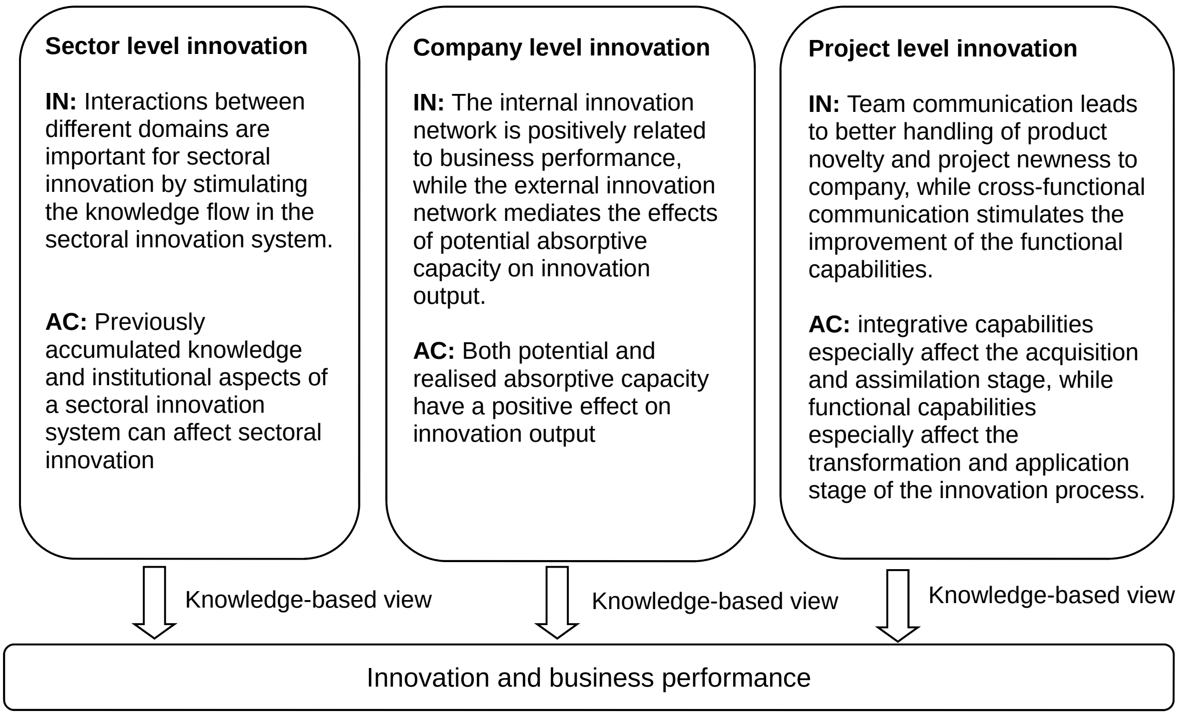


Figure 6.1 An integrated knowledge-based perspective on innovation and business performance in terms of the innovation network (IN) and absorptive capacity (AC) at the sectoral, company and project level

6.2.2 Methodological contribution

The vegetable breeding industry and the plant related research in the Netherlands are very internationally oriented. The main methodological contribution is that the social network analysis method was used to measure the international research network to identify the position of research institutes and companies in the Netherlands. The intensity of collaborations was measured by the co-authorship of joint scientific papers over a specific number of years. The interaction data were input into UCINET, a social network analysis method, and the longitudinal image of the structure of plant research collaboration networks and also the changes in the positions of players in the Netherlands over the years were presented. Besides the vivid image of the collaboration within research networks, it also provides the information about the structure of the network such as density, centrality, etc.

6.3 Limitations and directions for further research

6.3.1 Limitations

The findings of this study should be evaluated by taking the following limitations into account.

Some methodological limitations are related to a lack of longitudinal data. In Chapter 4 data about the innovation network, absorptive capacity and innovation and business performance at the company level were collected in 2010-2011. However, R&D investments and development of absorptive capacity might show a time lag. In Chapter 5, data were collected mainly based on on-going innovation projects, so the results of success or failure of the innovation projects were not yet available.

Extrapolation and generalization of results in this study need to be done very carefully. The sample of VBCs in China and the Netherlands reflects some unique characteristics of the plant breeding industry, which might not or only partly be translated to other industries.

6.3.2 Directions for further research

Previous research suggests that knowledge flows may considerably benefit from embeddedness in networks and the innovation network structure. (Audretsch and Feldman, 1996; Feldman and Audretsch, 1999; Burt, 2001; Reagans and McEvily, 2003; Nielsen, 2005; Fritsch and Kauffeld-Monz, 2010) . Several characteristics of the network could have a positive effect on innovation and business performance: network cohesion, heterogeneity of competences, density and tie strength of each actor's ego-network, the position of an actor in his ego-network and the individual characteristics of an actor etc. So it is worthwhile to extend this study with a quantitative analysis of the relationships in the innovation network and innovation performance. Such a study should focus either on the whole network by analysing the interaction of actors involved in the industry or focus on the ego-network in which a company or a research project is embedded. More specific characteristics of the innovation network, such as size, range, centrality and density could be measured and their effects on innovation and business performance tested.

In a Sectoral Innovation System, the important interactions are far more than just the collaboration in scientific research that is measured by jointly published papers. There are several other interactions that could be of interest for further research, e.g. the interactions between VBCs and research institutes and universities could be quantified by the number of public-private joint research projects, and the interactions between different VBCs could be measured based on the number of joint ventures, co-operation agreements and joint research projects.

6.4 Policy and managerial implications

The business landscape for the vegetable breeding industry has been subject to many changes in the last decades, both in China and the Netherlands, but innovation never ceased to be important. The plant breeding industry plays a crucial role in the first phase of food production and food processing. Innovations in plant breeding lead to improved varieties, which finally affect the whole supply chain. The vegetable breeding industry in China is developing fast with its access to one of the largest single markets but is experiencing a transition from a planned to a market economy. By contrast, the vegetable breeding industry in the Netherlands is firmly established and known to be the most innovative and outstanding in the world. Thus, although innovation is important for the breeding industry in both countries, there are large differences in the way it is supported and carried out. This last section aims to discuss the central research objective of the present study:

Investigate the influence of innovation networks, absorptive capacity and other key factors on innovation and business performance of vegetable breeding companies in China and the Netherlands.

By discussing this objective recommendations can be provided for politicians and managers in the vegetable breeding industry.

Governments should encourage both specialization and collaboration of different kinds of SIS actors to achieve better sectoral innovation performance

The present study of the sectoral innovation system of the vegetable breeding industries in China and the Netherlands reveals that knowledge flows among the different domains within this industry is a key factor in the improvement of innovation. This comparative study provides evidence that effective and successful innovation needs specialization of actors in their own domain and collaboration with actors in the other domains to acquire, integrate and apply knowledge in their own R&D. Specialization means that actors in their own domain should focus on what they are best at and accumulate knowledge from investments and previous experiences. Collaborations within the sector are important for accessing and integrating this external knowledge. In this study, quite some differences were observed in specialization and collaboration between the vegetable breeding industries in China and the Netherlands. In China, the government plays multiple roles in different domains, discouraging private sector investments and product innovation. It would be more effective to encourage specialization in the different domains, improving intellectual property protection, and stimulating R&D investments by the private sector. Collaboration could be stimulated by the creation and further development of intermediate organizations such as public-private partnerships (PPP) between breeding companies and research institutes. In the Netherlands, the business domain, the research & education domain and the intermediate organizations not only show an outstanding individual performance, which is based on continuous investments in innovation, but also, and more importantly, closely collaborate via public-private partnerships, research consortia, etc. Collaboration has become a cherished culture in the vegetable breeding industry in the Netherlands, which is not easy to copy, but methods to encourage collaboration are worth being adopted by others.

Companies should invest both in innovation networks and absorptive capacity to improve innovation and business performance

Our empirical study of the VBCs in China reveals that internal innovation networks have a direct effect and external innovation networks have an indirect effect on innovation output by amplifying the effect of potential absorptive capacity on innovation output. Absorptive capabilities positively contribute to the company's business performance only via improving innovation output, and not directly. In principle, there are two strategies to improve business performance: via an innovation network strategy or an absorptive capacity strategy. The optimum is to combine both strategies and extend and improve the external network and also improve the internal absorptive capacity in order to be able to make the most effective use of this external knowledge. Indeed, it was found that the fastest growing young VBCs actively use this combined strategy in China.

High levels of absorptive capacity and extensive innovation networks were identified in all VBCs in the Netherlands and these have certainly contributed to the outstanding position of this industry in the world.

Companies should encourage both team and cross-functional communication to ensure better innovation project performance

Our study showed that integrative capabilities play an essential role in the innovation process. From the perspective of absorptive capacity, it was further found that team communication is especially important at the acquisition and assimilation stages of an innovation project. It allows an innovation team to identify market potential and to interpret the ideas and transform them into novel innovation projects based on extensive discussions among team members. Cross-functional communication is important at the transformation and application stages of the innovation process and has a big impact on the successful commercialization of the product.

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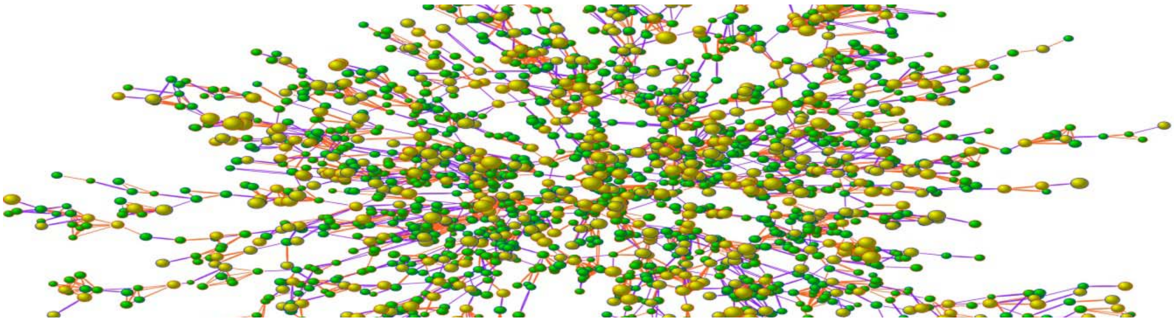
Appendices

Appendix 1- Company questionnaire



Innovation network and performance questionnaire

Especially for vegetable seed companies in the Netherlands and China

The questionnaire includes 62 questions in the following 8 sections:

1. Introduction
2. Business environment
3. Innovation strategy
4. Innovation input
5. Innovation network
6. Absorptive capacity
7. Innovation and business performance
8. Wrap up

1. Introduction

I. Please provide your respondent details

Name: ______________________________ Name of company: ______________________________

Department: ______________________________ Position: __________________________________

Phone: ______________________________ E-mail: ______________________________

II. Please describe your company's organization

Number of employees: __________________________ Number of R&D employees: ______________________

Turnover last year: _____________________________ R&D budget: ________________% of turnover

Company founded year: _________________________ R&D department founded year: __________________

Please choose

A. Is your company:

□ Independent
□ Part of a larger firm

B. If your company is part of a larger firm, please specify whether your company is:

□ Subsidiary
□ Division
□ Head office
□ Central R&D unit
□ Part of joint venture
□ Other: ___________

III. The two most important products of our company are: _________________________

① Tomato ② Pepper ③ Cucumber ④ Cabbage ⑤ Lettuce ⑥ Cauliflower ⑦ Watermelon ⑧ Melon ⑨ Carrot ⑩ Other___________

2. Business Environment

Each of the following items consists of a statement related to aspects of the industry, your company and its main competitors. Please circle the number that best fits your judgment

1. The sector is rich in investments and marketing opportunities:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

2. The average profit rate of companies in the vegetable seed industry in this country is:

Very low	1	2	3	4	5	6	7	Very high

3. In the last three years the number of vegetable seed companies has:

Decreased very much	1	2	3	4	5	6	7	Increased very much

4. Consumer trends and desires are easy to forecast:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

5. Governmental regulation for the vegetable seed industry is:

Very loose	1	2	3	4	5	6	7	Very strict

6. The threshold for entering the vegetable seed industry is:

Very low	1	2	3	4	5	6	7	Very high

7. New entrants in our sector has a strong influence on the business results of our company:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

8. The bargaining power of our growers has a strong influence on the business results of our company:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

9. The bargaining power of seed distributors has a strong influence on the business results of our company:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

3. Innovation strategy

Each of the following items consists of a statement related to aspects of the company strategy and culture. Please circle the number that best fits your judgment

10. Innovation is important to our company in maintaining competitiveness:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

11. Our firm fights the competition and is directed to market dominance:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

12. Senior managers actively participate in the selection of R&D projects:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

13. Senior managers are actively involved in the early stage of the innovation projects:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

14. The percentage of employees' bonus compared to their total payment:
① <5% ② 5%-10% ③ 10%-20% ④ 20%-30% ⑤ 30%-50% ⑥ >50%

15. The number of Plant Variety Rights granted to our company in the last three years:
① 0 ② 1-2 ③ 3-5 ④ 5-8 ⑤ above 8

16. Number of patents granted to our company in the last three years:
① 0 ② 1 ③ 2-3 ④ 4-5 ⑤ above 5

17. Among all the varieties of seeds that we sell the percentage that stems from:
In-house R&D ________ Bought from others: ________ In-licensed: ________
① <10% ② 10%-20% ③ 20%-30% ④ 30%-50% ⑤ >50%

18. Our company provides time and resources to undertake own projects:
① Employees do not have time to undertake own projects after appoint duty
② Our company neither encourages nor opposes employees to undertake own projects
③ Our company encourages employees to undertake their own projects
④ Our company supports employees to undertake their own projects after they finish their own duty

19. In the last three years fail of innovation projects happened mainly at the stage of:
① Feasibility studies ② Breeding new varieties ③ Field demonstration f ne varieties
④ Marketing of new varieties ⑤ Others: _____

20. The tolerance to failure in our company is:
① Failure in innovation is not acceptable, it shows insufficient effort.
② Failure in innovation is unavoidable, but if it happens too often the researchers' career will be negatively effected to some degree.
③ Failure is accepted in innovation, the researchers' career will never been negatively effected.

21. The frequency to report of project progress to senior management is on average:
① (More than) once per month ② Once per season ③ Once per half year ④ Once per year

4. Innovation Input

Each of the following items consists of a statement related to aspects of the company's resources input on innovation activities. Please circle the number that best fits your judgment or fill the options you choose.

22. In the last three years the R&D budget of our company: ____________ in the next three years: ____________

① Decreased substantially ② Decreased gradually ③ No change
④ Increased gradually ⑤ Increased substantially

23. Our R&D budget:
① Is a long term investment that is not influenced by annual changes in business performance:
② Is influenced by annual changes in business performance to some degree
③ Is influenced by annual changes in business performance to a large degree

24. The percentage of our R&D budget that is roughly spend on:
① In-house R&D projects _____%
② Outsourcing (e.g. to universities, research institutes, specialized technology firms and service providers) _____%
④ Collaborative research with other seed companies_____%
⑤ Other_____%

25. Please choose in which research fields your company conducts R&D (multiple answers possible):
① Breeding and selection of new cultivars ② Collection of new germplasm resources
③ Basic research (e.g. n w breeding methods) ④ Plant tissue culture(e.g. DH production)
⑤ Phytopathology research ⑥ Use of molecular markers
⑦ Use of genetic modification (GMO) ⑧ Genomics and bioinformatics
⑨ Seed technology (e.g. quality control, seed coating etc) ⑩ Other:

26. The priorities of the R&D investment (include internal and out-sourcing) in our company are:

(1) Breeding and selection for new varieties	Low priority	1	2	3	4	5	6	7	High priority
(2) Collection of new germplasm resources	Low priority	1	2	3	4	5	6	7	High priority
(3) Basic research (e.g. new breeding methods)	Low priority	1	2	3	4	5	6	7	High priority
(4) Plant tissue culture (e.g. DH production)	Low priority	1	2	3	4	5	6	7	High priority
(5) Phytopathology research	Low priority	1	2	3	4	5	6	7	High priority
(6) Use of molecular markers	Low priority	1	2	3	4	5	6	7	High priority
(7) Use of genetic modification(GMO)	Low priority	1	2	3	4	5	6	7	High priority
(8) Genomics and bioinformatics	Low priority	1	2	3	4	5	6	7	High priority
(9) Seed technology (e.g. quality control, seed coating etc.)	Low priority	1	2	3	4	5	6	7	High priority
(10) Other:	Low priority	1	2	3	4	5	6	7	High priority

27. The education level of employees in our company:
(1) With technical/professional degree _________ (2) With Bachelor degree _________
(3) With Master degree _________ (4) With Doctor degree _________
① <5% ② 5%-10% ③ 10%-20% ④ 20%-30% ⑤ 30%-50% ⑥ >50%

28. Our company provides different kinds of training programs to our employees: (multiple choices possible):
① Internal training ② External training ③ Participatory learning
④ Mentor project ⑤ Online learning courses ⑥ Other:_____

29. The training topics are (multiple choices possible):
① Business/technical skills ② Communication skills ③ Foreign languages
④ Teamwork ⑤ Target management ⑥ Time management
⑦ Leadership and management ⑧ Marketing ⑨ IT
⑩ Other: _____

30. The average training time per year that is offered to our employees is:
① (Less than) 1 day ② 1 o 3 days ③ 3 days to 1 week
④ 1 week to 1 month ⑤ More than 1 month

31. Which kind employees receive the most training?
① New employees ② First line managers ③ Middle managers ④ Senior managers

32. Employees from which department(s) have the best training opportunities (multiple choices possible):
① R&D department ② Marketing department ③ Sales department
④ Production and logistic department ⑤ Other:_____

5. Innovation network

Each of the following items consists of a statement related to internal and external linkage of the firm. Please include the number or letter that best fits your judgment.

33. Our company has a good communication and collaboration with:

(1) Growers	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(2) Seed distributors	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(3) Seed retailers	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(4) Vegetable distributors	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(5) Vegetable retailers	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(6) Local government:	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(7) National government	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

34. Applying for governmental financial support for innovation projects is:

Very difficult	1	2	3	4	5	6	7	Very easy

35. Did our company get governmental financial support for innovation projects in the last 3 years? □ Yes □ No
If yes, please describe the reason to participate in this kind of projects: (multiple choices)
① Our company got a subsidy to reduce R&D costs ② To lower R&D risks
③ To monitor technological developments ④ Build-up our R&D network
⑤ Improve the time-to-market ⑥ Build brand name
⑦ Other: _____

36. Our company:
① Has no contact and collaboration with universities and research institutes
② Keeps in close contact with universities and research institutes
③ Conducts collaborative projects with universities and research institutes

37. Our company is a member of the following associations(multiple choices possible):
① Plantum NL ② CSA(China Seed Association)
③ Productschap Tuinbouw (Dutch Horticultural Product Organization) ④ CSTA (China Seed Trade Association)
⑤ ESA (European Seed Association) ⑥ CSHS (China Society of Horticulture Science)
⑦ ISF (International Seed Federation) ⑧ Provincial Seed association in China
⑨ ISHS (International Society of Horticulture Science) ⑩ APSA(Asia Pacific Seed Association)

38. Our company uses the following consultancy services(multiple choices):
① Marketing research ② Legal and IP consultant ③ IT
④ Human resource plan consultant ⑤ Logistic ⑥ Public relationship
⑦ Strategy ⑧ Finance ⑨ Other:_____

39. In the last three years, **the number of innovation partners** with whom we collaborate is (put √in the grids that best fit your judgment):

Innovation partner	None	1-3	4-7	8-10	11-15	16-30	Over 30
(1) Our main suppliers							
(2) Our main customers							
(3) Other seed companies							
(4) Universities and research institutes							
(5) Governmental agencies							
(6) Association/organizations							
(7) Consultancy services							

40. In the last three years, **the frequency we communicate** with our innovation partners is (put √in the grids that best fit your judgment):

Innovation partner	None	Once to twice per year	Less than once per month	Once to twice per month	Three to four times per month	Once to twice per week	Over twice per week
(1) Our main suppliers							
(2) Our main customers							
(3) Other seed companies							
(4) Universities and research institutes							
(5) Governmental agencies							
(6) Association/organizations							
(7) Consultancy services							

41. **The average duration of the relationship** with our innovation partners is (put √in the grids that best fit your judgment):

Innovation partner	Less than 1/2 year	1/2-1 year	1-2 years	3-4 years	5-8 years	Over 8 years
(1) Our main suppliers						
(2) Our main customers						
(3) Other seed companies						
(4) Universities and research institutes						
(5) Governmental agencies						
(6) Association/organizations						
(7) Consultancy services						

42. Please, give the names(or abbreviations or even code as "A,B,C,D,E" if confidential) of the 5 most important innovation partners and their relevant information:

No.	Abbreviation or code name of innovation partners	Type (please use the figures) 1=supplier; 2=customer; 3=other seed companies; 4= university or research institute; 5= governmental agency; 6= association; 7= consultancy service; 8=others	Area (please use the figures) 1=same town as our company; 2=same region; 3=same province; 4=same country; 5=foreign country; 6=others
P1.			
P2			
P3.			
P4.			
P5.			

43. Please choose the methods/tools that your company uses in collaboration with the 5 most important innovation partners (multiple answers are possible, give a √ to the □ that fit your judgment)

□ Joint R&D project.	□ Technology license in/out	□ Joint venture	□ Technical exchange	□ R search consortium
□ Introduction of advanced equipments	□ Joint production	□ Excursion to field trials	□ IP protection	□ Venture capital
□ Joint branding	□Joint marketing	□ Employees	□Consultancy in	□ Consultancy

		training	technology or law	in operatio
□ Discussion on (inter)national policy	□ To understand trends in technology	□To understand trends in industry	□ Sponsoring exhibitions/conferen ces	□ Others: ____________

44. The R&D department plays a central role in our company:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

Please specify which department(s) have close linkages to the R&D department:

(1) Sales	Not close	1	2	3	4	5	6	7	Very close
(2) Marketing	Not close	1	2	3	4	5	6	7	Very close
(3) Production	Not close	1	2	3	4	5	6	7	Very close
(4) Logistics	Not close	1	2	3	4	5	6	7	Very close
(5) Finance	Not close	1	2	3	4	5	6	7	Very close
(6) Human resources	Not close	1	2	3	4	5	6	7	Very close
(7) IP	Not close	1	2	3	4	5	6	7	Very close
(8) ICT	Not close	1	2	3	4	5	6	7	Very close
(9) Others, namely………	Not close	1	2	3	4	5	6	7	Very close

6. Absorptive capacity

45. Through the communication and collaboration with our main innovation partners, our company can:

Strongly disagree ←----------→ Strongly agree

(1) Acquire more technical knowledge	1	2	3	4	5	6	7
(2) Acquire more market information	1	2	3	4	5	6	7
(3) Acquire more professional talents	1	2	3	4	5	6	7
(4) Acquire more pertinence in product development	1	2	3	4	5	6	7
(5) Acquire more ideas for product development	1	2	3	4	5	6	7
(6) Acquire more ideas for process improvement	1	2	3	4	5	6	7
(7) Seize market opportunities more easily	1	2	3	4	5	6	7

46. In order to stimulate communication and collaboration:

Strongly disagree ←----------→ Strongly agree

(1) Our company favours an environment for employees that stimulates discussion, such as chat and coffee rooms	1	2	3	4	5	6	7
(2) Our company finds networking competence a basic requirement for the recruitment of new employees	1	2	3	4	5	6	7
(3) Our company finds networking competence a basic element of the employees' performance assessment	1	2	3	4	5	6	7
(4) Our company encourages employees to know other work procedures than those of their own department	1	2	3	4	5	6	7
(5) Our company provides job rotation possibilities to people of different departments when needed	1	2	3	4	5	6	7
(6) Our company arranges informal activities to improve understanding among different departments	1	2	3	4	5	6	7
(7) Outside the work situation, employees communicate frequently	1	2	3	4	5	6	7
(8) There are many innovation teams in which different ranks of employees collaborate	1	2	3	4	5	6	7
(9) Generally, we use cross-functional innovation teams to organize our work	1	2	3	4	5	6	7
(10) We regard training of employees as an investment for our company, not as a cost	1	2	3	4	5	6	7
(11) We share a common vision: once we stop learning our future will be in danger	1	2	3	4	5	6	7
(12) We consistently codify the 'lessons learned' at the	1	2	3	4	5	6	7

end of innovation projects							
(13) We monitor on a regular basis the extent to which our products and processes align to our customers' needs	1	2	3	4	5	6	7
(14) We attend exhibitions and trade fairs more frequently than our competitors	1	2	3	4	5	6	7
(15) We rarely cancel external collaboration projects for reasons of lack of money	1	2	3	4	5	6	7
(16) Our company uses joint ventures and alliances to make full use of our R&D capabilities	1	2	3	4	5	6	7
(17) There is an excellent communication of R&D and growers	1	2	3	4	5	6	7
(18) There is an excellent communication of R&D and distributors	1	2	3	4	5	6	7
(19) There is an excellent communication of R&D and production	1	2	3	4	5	6	7
(20) There is an excellent communication of R&D and marketing & sales	1	2	3	4	5	6	7

7. Innovation and business performance

Each of the following items consists of a statement related to the situation in your company. Please circle the number that best fits your judgment

47. The current position of our company compared to our main competitors can be characterized as:

Follower	1	2	3	4	5	6	7	Ahead of competition

48. Our company distinguish itself positively compared **to the market leader** by:

(1) A strong financial position	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(2) An effective R&D process	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(3) Our good reputation in the market	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(4) Our flexibility of market response	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(5) The education level of our employees	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(6) The protection that our products and processes receive by patents, licenses, etc.	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

49. Our company distinguishes itself positively compared **to our main competitors** by:

(1) A strong financial position	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(2) An effective R&D process	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(3) Our good reputation in the market	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(4) Our flexibility of market response	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(5) The education level of our employees	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
(6) The protection that our products and processes receive by patents, licenses, etc.	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

50. The main competitive strength(s) of our company are:

(1) Price	Not competitive	1	2	3	4	5	6	7	Very competitive
(2) Quality	Not competitive	1	2	3	4	5	6	7	Very competitive
(3) Delivery	Not competitive	1	2	3	4	5	6	7	Very competitive
(4) Customer relationships	Not competitive	1	2	3	4	5	6	7	Very competitive
(5) Uniqueness of products	Not competitive	1	2	3	4	5	6	7	Very competitive
(6) Technical excellence	Not competitive	1	2	3	4	5	6	7	Very competitive

51. Our new products enter the market faster compared to our main competitors' products:

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

52. Compared to our main competitors, our sales (in euros)is:

Much lower	1 2 3 4 5 6 7	Much higher

53. We expect the sales volume of our current products in the coming three years to:

Strongly decrease	1 2 3 4 5 6 7	Strongly increase

54. The market share of our first main product is growing quickly:

Strongly decrease	1 2 3 4 5 6 7	Strongly increase

55. The market share of our second main product is growing quickly:

Strongly decrease	1 2 3 4 5 6 7	Strongly increase

56. Our sales is highly dependent on new products which are launched to the market in the last three years:

Strongly disagree	1 2 3 4 5 6 7	Strongly agree

Please specify the percentage of sales generated by new products: _______________

① <5% ② 5%-10% ③ 10%-20% ④ 20%-30% ⑤ 30%-50% ⑥ >50%

57. Compared to our main competitors, our yearly growth rate (average percentage over the last 3 years) is:

Much lower	1 2 3 4 5 6 7	Much higher

Please specify the percentage of yearly growth rate: _______________

① <5% ② 5%-10% ③ 10%-20% ④ 20%-30% ⑤ 30%-50% ⑥ >50%

58. Compared to our main competitors, our operating profit margin (operation results/revenue) is

Much lower	1 2 3 4 5 6 7	Much higher

Please specify: _______________

① <5% ② 5%-10% ③ 10%-20% ④ 20%-30% ⑤ 30%-50% ⑥ >50%

59. The returns from R&D relative to the R&D investments are:

Very unsatisfactory	1 2 3 4 5 6 7	Very satisfactory

60. How innovative would you consider your company to be in the following?

(1) R&D	Not innovative	1	2	3	4	5	6	7	Very innovative
(2) Breeding processes	Not innovative	1	2	3	4	5	6	7	Very innovative
(3) Product production and logistics	Not innovative	1	2	3	4	5	6	7	Very innovative
(4) Marketing	Not innovative	1	2	3	4	5	6	7	Very innovative
(5) Distribution	Not innovative	1	2	3	4	5	6	7	Very innovative

8. Wrap up

61. Are you willing to participate in follow-up on this survey and future research of this type? ☐ yes ☐ no

62. Please add any remarks or recommendations for improving this survey

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Appendix 2- Project questionnaire- Wageningen Innovation Assessment Tool

General information
Name company:……………………………………………………..
Name project/product:…………………………………………………
Name employee:…………………………………………………….
Department:…………………………………………………………
E-mail:………………………………………………………………
Date:…………………………………………………………………

Your position / function:

O R&D	O Sales	O Marketing
O Production	O Supply chain	O Finance
O Human resources	O Management	O IP
O ICT	O ICT	

Tenure

Years in this industry ………….	Years with this employer ………….	Years with this position ………….

This questionnaire includes two parts: **1. Innovation Assessment Tool** to measure your project and its product and market; **2.Network Assessment Tool** to measure your innovation network structure.

Part I. Innovation Assessment Tool

Introduction: This part is based on Wageningen Innovation Assessment Tool to identify the key success factors of innovation project.

Agreement: Do these characteristics describe the project? Indicate your degree of agreement or disagreement by entering a number on a 1 to 10 scale in the column **"Answer"**. Here 1 means strongly disagree and 10 means strongly agree. Numbers between 1 and 10 indicate various degrees of agreement or disagreement.

Certainty: You are also asked to indicate how certain or confident you are about each of your responses by entering a number on a 1 to 10 scale in the column **"Confidence"**. Here 1 means very low confidence in your answer, highly uncertain and 10 means total confidence in your answer, highly certain. Numbers between 1 and 10 indicate varying degrees of confidence.

Example

Nr.	Statements	**Answer** 1… 10	**Certainty** 1… 10
9	Our financial resources are more than adequate for this project.	***8***	***5***

In this example an "8" is given as **answer**. This would mean that you agree quite strongly with this statement. You filled in a "5" for **certainty.** This means you are not very confident about your answer, for example because you are not involved in the project finances.

Advice
Don't think too long for each answer, most of the times your first thought is the right one. Completing this part will take approximately 20 minutes. Please answer for all the statements, even if it is difficult to make an indication.

The Statements

Nr	Statements	Agreement 1… 10	Certainty 1… 10
1	The product type is totally new for our company(e.g. new crops, etc.).		
2	We have never made or sold products to satisfy this type of customers need or use before (e.g. new disease-resistant, new shape, etc.).		
3	The potential customers for this product are totally new for the company(e.g. new area, new type of customers, etc.).		
4	The technology required to develop this product is totally new to our company.		
5	The nature of the production process is totally new for our company.		
6	The distribution system and/or type of sales-force for this product is totally new to our company.		
7	The type of advertising and promotion required is totally new to our company.		
8	The competitors we face in the market for this product are totally new to our company.		
9	Our financial resources are more than adequate for this project.		
10	Our engineering skills and people are more than adequate for this project.		
11	Our production resources or skills are more than adequate for this project		
12	Our marketing research skills and people are more than adequate for this project.		
13	Our advertising and promotion resources and skills are more than adequate for this project.		
14	Our sales and/or distribution resources and skills are more than adequate for this project.		
15	I have enough communication with my team members to do my work efficiently and in an effective way.		
16	In this project, I am the one who most frequently requires information and support from other team members.		
17	In this project, I am the one who most frequently provides information and support to other team members.		
18	I knew the team members well before the start of this project.		
19	In this project, it is easy to talk to everyone you need, regardless of rank, position, or organisation.		
20	The cooperation with marketing and sales is essential for the success of this project.		
21	We always give other departments (e.g. M&S, manufacturing, etc.) the information they ask for.		
22	We always get the information from other departments (e.g. M&S, manufacturing, etc.) we ask for.		
23	The performance requirements for this project are clear for me.		
24	In a new project I surely want to participate in the current team again.		
25	All our team members are focused on “collecting” knowledge for our project.		
26	I am completely satisfied with the product development process used.		
27	Our product will be clearly superior to competing products in terms of meeting customers’ needs.		
28	Our product will be of higher quality than competing products.		
29	Compared to competitive products, our product will offer a number of unique features or attributes to the customer.		
30	Our product will permit the customer to do a job or do something he/she cannot presently do with what is available.		
31	Our product will permit the customers to reduce their overall costs, when compared to what they use now.		
32	Our product is highly innovative totally new to the market.		

33	Our product is a very high technology one.		
34	Our product is mechanically and/or technically very complex.		
35	Our product will be first into the market.		
36	The market is a highly competitive one.		
37	There are many competitors in this market.		
38	There is a strong dominant competitor – with a large market share – in the market.		
39	There is a high degree of loyalty to existing (competitors') products in this market.		
40	The market is characterized by intense price competition.		
41	The market for this product is growing very quickly.		
42	Potential customers have a great need for this type of product.		
43	The customer will definitely use the product.		
44	This product has a high potential (i.e. can additional products, multiple styles, price ranges).		
45	This project will contribute to the competitive advantage of the company.		
46	This new product will surely meet the applicable laws (e.g. product liability, regulations, and product standards).		
47	This new product will surely have a positive effect on the environment.		

If your project is an open innovation project with external partner(s), please fill in the following questions

48	The cooperation with our partner(s) is essential for the success of this project.		
49	We always give our partner(s) the information they ask for.		
50	We always get the information from our partner we ask for.		
51	Number of external partner(s)……………….		

Please indicate for the following items the probability on a scale of 1-10 (1 very low probability, 10 very high probability)

		Probability 1… 10
	Expected project performance	
a	What is the probability that this project will be completed within the original planning?	
b	What is the probability that this project will be completed within the original budget?	
c	What is the probability that this project fulfils all its objectives?	
d	What is the probability that this project will directly benefit the end-users (either through increasing efficiency or effectiveness)?	
e	What is the probability that this project will earn more money for the company than it costs?	
f	What is the probability that this project will have a major spin-off or springboard effect, a step in the development of a new generation of products?	
g	What is the probability that this project will improve customers' loyalty to the company?	

Part II. Network Assessment Tool

Introduction: This part is designed to help you identify patterns of your network. Your "network " refers to the set of relationships that help you access useful information, get things done, and more generally, develop personally and professionally.

Directions: Follow the instructions Step 1 to Step 2 on the following pages. The information will be used for this research purpose only, and will not share with any third parties. Completing this part will take approximately 15 minutes .

Step 1: List your network contacts

It is not necessary to limit yourself to individuals who work for the same company. People with whom you have more than one kind of relationship can be listed more than once. (For each question, list as a few or as many names as you want, up to maximum of 4 names, if you think giving the names of your network contacts is too private, you can just use the abbreviation, such as you can use " HV" represent " Hans Vesser")

A. **Discussing new business idea and technical solutions** If you look back over the last three years, what people have been most helpful? Consider people who have provided leads, offer advice, or who may have inspired you ideas for important project, new trend, opportunities, techniques, or any other matters of importance to your work.

   ……………… ……………… ……………… ………………

B. **Supporting your project** Consider an important new project or initiative that you are promoting, list those people who would be influential for getting it approved or obtaining resources you need.

   ……………… ……………… ……………… ………………

C. **Socializing informally** Who do you socialize with? Socializing includes spending time with people after working hours, visiting one another at home, going to social events, going out for meals, and so on. Over the last three years, who are the main people with whom you have socialized informally?

   ……………… ……………… ……………… ………………

Step 2: Fill in Network Characteristic Grid

Consolidate the names listed in Step 1 onto the **Network Characteristic Grid on Page 5**. ***No one name should be listed twice.*** Then use the options below to describible your network characteristic.

Example: Assuming "Hans Vesser" is one of your network contacts, in the **Network Characteristic Grid,** an "a"、"b"、"a"、"b"、"c"、"a"、"a" and "4" given respectively as answer to question 1) to 8). This would mean that you think "Hans Vesser" has the same gender as you; his age is different from you in 5 years; he has same nationality and formal education level as you; he works in the similar industry, but higher position than you; you are keep in touch more than once every week, and closeness of the relationship is 4. For question 9), three checkmark "√" are given to contact person 4, 6 and 7, which means you think "Hans Vesser" knows your contact person 4, 6 and 7.

1. Gender
   a. Same as you　　　　　　　　b. Opposite from you

2. Age
   a. Younger than you by 6 years or more
   b. Your age, plus or minus 5 years
   c. Older than you by 6 years or more

3. Nationality
   a. Same as you　　　　　　　　b. Different from you

4. Education

a. Less formal education than you
b. Same formal education as you
c. More formal education than you

5. Industry
   a. From same unit/office/division in your company
   b. From different business unit/division/office in your company
   c. From different company/organization but in a similar industry
   d. From other industry

6. Position
   a. Higher up than you in your or another organization
   b. Same level as you in your or another organization
   c. Lower than you in your or another organization

7. Contact intensive
   a. Once per week b. Once per month c. Once per half year

8. Closeness
Please use figure 1 to 5 to describe the closeness between you and the contact person, Here 1 means not close at all and 5 means very close. Numbers between 1 and 5 indicate various closeness.

9. Whether Contact person knows each other?
In the Network Characteristic Grid, indicate who knows each other in your network by placing a checkmark "√" in the cells corresponding to each acquainted pair. Leave a cell blank if the pair do not know each other, or if you do not know whether they know each other.

Network Characteristic Grid

	1. Gender	2. Age	3. Nationality	4. Education	5. Industry	6. Position	7. Contact	8. Closeness	9. Whether Contact person knows each other?										
Contact person									2	3	4	5	6	7	8	9	10	11	12
Hans Vesser	**a**	**b**	**a**	**b**	**c**	**a**	**a**	**4**			√		√	√					
1________																			
2________																			
3________																			
4________																			
5________																			
6________																			
7________																			
8________																			
9________																			
10_______																			
11_______																			
12_______																			

Thank you very much for filling out this questionnaire!

Summary

The seed business plays a crucial role at the basis of the food supply chain, and companies which are active in plant breeding and production and sales of seeds are embedded in a competitive environment. They continuously face challenges to develop higher yielding varieties with better or new qualities, optimized for sustainable production under a wide variety of growing conditions. To meet those challenges innovation through R&D is extremely important. For this study, I chose the vegetable breeding industry as the subject of this research and focused on two similar business sectors in two different parts of the world, China and the Netherlands. In China the vegetable breeding industry is developing fast, has access to an exceptionally large internal market, and is experiencing a transition from a planned to a market economy. In 2013 the total number of licensed seed companies was approximately 6,500. Most of them, however, are only active in seed trade. There were 112 true vegetable breeding companies (VBCs), active in breeding new varieties, seed production and sales. These companies were divided in 1) public VBCs, often originating from vegetable research institutes; 2) domestic private VBCs; and 3) foreign private VBCs, including wholly foreign-owned subsidiaries and joint ventures. In contrast to the situation in China, the vegetable breeding industry in the Netherlands is an established industry, which has developed into one of the most innovative and outstanding in the world. It accounts for one third of the world's vegetable seed exports and one eighth of the world's vegetable seed imports. Due to a period of consolidation the top ten VBCs in the world account for over 85% of the global vegetable seed market. Most of these companies originated in the Netherlands or have important R&D facilities in the Netherlands. Innovation is important for the vegetable breeding industries in both countries although they are at different stages of development. The objective of this thesis was to investigate the influence of innovation networks, absorptive capacity and other key factors on innovation and business performance of VBCs in China and the Netherlands.

Knowledge is the most important source of a company's sustainable competitive advantage, and is the basis for its core competencies, especially the capability of innovation. In this study, the knowledge-based view was, therefore, used as a framework to analyse the factors influencing innovation and business performance. The research was carried out using a 'mixed' methodology by collecting both qualitative and quantitative data in both China and the Netherlands, and integrating the analysis at the sector, company and project level.

Innovation at sector level

The first part of the present thesis focuses on innovation at the sectoral level of the vegetable breeding industry, because innovation is not only based on the creativity of an individual entrepreneur, researcher, company or research institute, but rather the result of interaction and co-operation within a much larger system (Feinson, 2003; Dodgson et al., 2008a). The sectoral innovation system, used as one of the research frameworks in this thesis, has been widely used to analyse such broader context. It is based on the premise that understanding the linkages among the different actors involved in innovation processes, and focusing on the importance of socially embedded knowledge and learning, is key to understanding innovation performance. Malerba (2002) found that knowledge and learning is the key determinant of innovation, and Cohen and Levinthal (1990) also indicated that the interaction between a company's own and external knowledge stocks is important for innovation performance. In this study, the innovation framework of Arnold and Bell (2001) was further developed with emphasis on analysing the knowledge flow between different domains (business, research & education, and intermediate organizations) and the institutional aspects that affect knowledge stocks and knowledge flow (market demand and the infrastructure & framework conditions). In order to improve the understanding of the complexity of factors that are related to the innovation and business performance, the research question addressed was:

Research Question 1 (RQ1): what are the main drivers and barriers for an effective and well-functioning sectoral innovation system in the cases of China (Chapter 2) and the Netherlands (Chapter 3)?

The study in Chapter 2 led to the conclusion that lack of interaction and knowledge flow between different domains constrains the innovation of the vegetable breeding industry in China. The study in Chapter 3, on the other hand, led to the conclusion that the outstanding innovation level of the vegetable breeding industry in the Netherlands is not only based on an outstanding performance of each domain of SIS separately, but also on good interactions between different domains. So both studies in China and the Netherlands indicated the importance of interaction between different domains for innovation in the sector, but the approaches to stimulating innovation at the sector level were quite different.

In the Chinese vegetable breeding industry, the government played multiple roles with public organizations being active as important actors in all three relevant domains within the sector: business domain, research & education domain and intermediate domain. Large governmental investments in research organizations and state-owned companies have discouraged investments by private companies. Besides, there are only a limited number of intermediate organizations that aim to stimulate and facilitate collaborations in

R&D. So the innovation network has been constrained and this has led to the limited knowledge flow between and within the different domains.

By contrast, the actors in the different domains of vegetable breeding industry in the Netherlands are specialized within their domain and intensively collaborate with actors in the other domains. The government plays a supportive and facilitating role to encourage different actors to innovate in their own domains by favourable policies and stimulates initiatives to build collaboration platforms of actors across domains. The R&D activities of organizations within the different domains have built knowledge stocks and absorptive capacities, while innovation networks are organized to facilitate the knowledge flow between different domains.

Therefore, key drivers for a successful innovation system are the specialization of actors within their own domains and collaboration of actors across different domains. Constraints in knowledge transfer between the domains can be considered one of the main innovation barriers.

Innovation at company and project level

Taking into account the technological and managerial complexity of product development, companies are no longer able to do all innovation activities within their own premises. In innovation management literature it has become generally acknowledged that companies rarely innovate alone, but are embedded in dense networks of contacts and collaborations with external innovation partners, such as supply chain partners, universities and research institutes, intermediate organisations, consultants, governmental organizations, and even competitors (Granstrand et al., 1992; Gemünden et al., 1996; Spender, 1996; Cobbenhagen, 1999; Omta et al., 2002; Laursen and Salter, 2006; Dodgson et al., 2008b; Batterink, 2009; NSF, 2012). Such innovation networks enable companies to get access to knowledge and resources that they do not possess themselves. However, knowledge is not freely available, often of a tacit nature, and highly context-specific. It requires companies to have the absorptive capacity to recognize the value of new, external information, assimilate it, and apply it to commercial ends. To study this, the input-throughput-output model of innovation processes was adopted and applied first at the company level, by focusing on the internal and external innovation network of VBCs and on their potential and realized absorptive capacity at the throughput stage of innovation processes. Subsequently, the impact of absorptive capacity was studied at the project level at the four stages that can be recognized in the innovation process: acquisition, assimilation, transformation and application. Accordingly, the research question addressed in Chapter 4 and 5 was:

Research Question 2 (RQ2): what is the role of the innovation network and the absorptive capacity for a company's innovation and business performance at the company (Chapter 4) and project (Chapter 5) level.

To answer Research Question 2 at company level empirical data were collected by using a survey questionnaire adapted from the Wageningen Innovation Assessment Toolkit (WIAT), and by conducting semi-structured interviews with senior managers of 51 VBCs in China. To answer Research Question 2 at project level empirical data of 68 innovation projects in VBCs were collected using a WIAT-derived project questionnaire in both China and the Netherlands.

The study in Chapter 4 led to the conclusion that VBCs can achieve improved business performance using two main strategies. The first is an absorptive capacity strategy, by which a company improves its absorptive capacity, then achieves a higher innovation level and increases its competitive strength. The second is an innovation network strategy, by which a company achieves better business performance by improving its innovation network. It was shown that the quality of the external network mediates the effect of potential absorptive capacity on innovation output; the internal innovation network was shown to be positively related to innovation output. So the innovation network strategy could enlarge the effect of absorptive capacity by accessing and making effective use of external knowledge. VBCs were recommended to combine these two strategies to extend and improve their external network and to improve their absorptive capacity in order to be able to make effective use of this external knowledge. In fact, it was found that the fast growing young VBCs already started to use this combined strategy.

The study in Chapter 5 led to the conclusion that the four stages of innovation processes dynamically interact with each other, and integrative capabilities play an essential role. Team communication proved to be important in the acquisition and assimilation stages to identify, discuss and interpret external information for use in an innovation project. Cross-functional communication was especially important at the transformation and application stage, where it is known to help overcome barriers created by the novelty of an innovation project. This is especially relevant in the vegetable breeding industry where the product development cycle is relatively long. Cross-functional communication will improve relevant functional capabilities necessary for supporting the development and marketing of new products.

The results of this study make several contributions to existing theories. These can be listed as follows:

- This study uses the knowledge-based view theory to explain the sectoral, company and project innovation performance. This theory was so far used only at company level (Kogut and Zander, 1996; Spender, 1996; Blindenbach-Driessen and van den Ende, 2006; Dodgson et al., 2008a; Lopez and Esteves, 2013), but was extended here to also analyse the sector and project level. The sectoral innovation systems approach was used to analyse innovation at sector level and the absorptive capacity perspective was used to analyse innovation processes at project level.

- A multi-dimensional measurement of potential and realized absorptive capacity was constructed to empirically validate the theoretical contribution of Zahra and George (2002). The measurements of internal and external innovation networks were also added, thereby extending the study of Camisón and Forés (2010), which only empirically studied absorptive capacity. In this way the combined effect of innovation network and absorptive capacity on innovation output was found.

- This thesis extended studies on innovation processes at the project level (Borsi and Schubert, 2011; European Commission., 2011; ISF, 2011b; LEI, 2012; NSF, 2012) from the absorptive capacity perspective, by analysing the interaction of factors in the four stages (acquisition, assimilation, transformation and application) of the innovation process, in order to find the key factors that affect innovation project performance. Team communication and cross-functional communication play important, yet different roles at different stages of the innovation process at project level.

In general, the present study provides more insight into the role of innovation network (Newman, 2010; Omta and Fortuin, 2010; Schoubroeck and Kool, 2010) and absorptive capacity (Pavitt, 2002; Daghfous, 2004) which are two important parameters in understanding innovation and business performance at different levels. The combined effects of innovation network and absorptive capacity on innovation and business performance were also studied in this thesis.

The implications of this study for the vegetable breeding industry are the following. It was advised that governments should encourage both specialization and collaboration of actors in the different domains of the industrial sector to achieve better sectoral innovation performance. It is important for the actors in the different domains of the vegetable breeding industry to accumulate knowledge by their own investment in R&D and gain external knowledge by collaboration. Companies should invest in both innovation networks and absorptive capacity, because the innovation network will enlarge the effect of absorptive capacity on innovation output and business performance. Furthermore, companies should encourage both team and cross-functional communication to ensure better project performance. Team communication plays an important role in the acquisition and assimilation stage of an innovation project and could help the project team to develop new ideas and to identify market potential. Cross-functional communication is important at the transformation and application stage and will help to develop related functional capabilities for supporting the development and marketing of new products.

Samenvatting

Dit onderzoek werd geïnitieerd door de cruciale rol die de internationale zaadindustrie speelt aan de basis van de voedselproductieketen, waardoor de economische effecten van innovatie groot kunnen zijn. Bedrijven die actief zijn in de veredeling van gewassen en in de productie en verkoop van zaden voeren hun activiteiten uit in een zeer competitieve omgeving. Ze hebben te maken met voortdurend veranderende uitdagingingen zoals het leveren van een bijdrage aan de voedselzekerheid, de noodzaak om nieuwe rassen te ontwikkelen die een hoge opbrengst en hoge kwaliteit producten leveren en die gebruikt kunnen worden voor een duurzame productie. Om die uitdagingen aan te kunnen gaan is innovatie in R&D van groot belang. Voor dit onderzoek hebben we gekozen voor innovatie in de groenteveredeling in twee identieke sectoren, maar in twee verschillende delen van de wereld, China en Nederland. De groenteverdelingsindustrie in China ontwikkelt zich snel met een zeer grote interne markt en geleid door een snelle transitie van een planeconomie naar een markteconomie. In 2013 werd het totale aantal zaadbedrijven met vergunning geschat op 6500, maar veruit de meeste daarvan zijn alleen actief in de handel van zaden. Uit ons onderzoek bleek dat er in China slechts 112 geïntegreerde groenteveredelingsbedrijven (GVBs) zijn, die actief zijn in de ontwikkeling van nieuwe rassen, de productie van zaden en de verkoop van zaaigoed. We hebben deze bedrijven onderscheiden in 1) publieke GVBs, vaak afkomstig uit onderzoeksinstellingen van de overheid; 2) binnenlandse particuliere GVBs; en 3) buitenlandse particuliere GVBs, met inbegrip van volledige dochterondernemingen en joint ventures. In tegenstelling tot China heeft de groenteveredelingsindustrie zich in Nederland al heel lang ontwikkeld en heeft een zeer hoog niveau van innovatie en kwaliteit bereikt. De sector verzorgt een derde van de exportwaarde van groentezaden in de wereld en een achtste van de importwaarde. Als gevolg van een jarenlang proces van consolidatie zijn de top tien GVBs in de wereld verantwoordelijk voor meer dan 85% van de wereldwijde groentezaadmarkt. De meeste van deze bedrijven hebben hun oorsprong in Nederland of hebben belangrijke R & D faciliteiten in Nederland. Innovatie in de plantenveredeling is belangrijk voor beide landen, hoewel ze in zeer verschillende stadia van ontwikkeling verkeren. Het doel van dit onderzoek was na te gaan wat de invloeden zijn van innovatienetwerken, absorptievermogen en andere sleutelfactoren op de innovatie en economische prestaties van GVBs in China en Nederland.

In deze studie hebben we factoren die innovatie en economische prestaties beïnvloeden vanuit de “knowledge-based view” geanalyseerd, want kennis is de belangrijkste bron van duurzaam concurrentievoordeel voor een bedrijf. Kennis vormt de basis voor haar kerncompetenties, in het bijzonder het vermogen tot innovatie. Het onderzoek werd uitgevoerd met behulp van een 'gemengde' methodologie waarbij zowel kwalitatieve als kwantitatieve gegevens in China en Nederland verzameld werden en vervolgens geïntegreerd tot een analyse op sector-, bedrijfs- en projectniveau.

Innovatie op sectorniveau

Het eerste deel van dit proefschrift richt zich op innovatie op sectorniveau binnen de groenteveredelingsindustrie. Management van innovaties vereist een goed begrip van de brede sectorale context waarin het zich voordoet en de aard van het innovatieproces (Dodgson et al., 2008a). Innovatie is niet alleen gebaseerd op de creativiteit van individuele ondernemers, onderzoekers, bedrijven of onderzoeksinstellingen, maar zeker ook het gevolg van interactie en samenwerking binnen een groter systeem (Feinson, 2003). Het sectorale innovatiesysteem (SIS), in dit onderzoek toegepast als onderzoekskader, wordt vaak gebruikt om deze bredere context te analyseren. Het is gebaseerd op de vooronderstelling dat inzicht in de verbanden tussen de verschillende actoren die betrokken zijn bij innovatieprocessen, met nadruk op het belang van sociaal ingebedde kennis en kennisoverdracht, de sleutel is tot een begrip van innovatieprestaties. Malerba (2002) vond dat kennis en kennisoverdracht de belangrijkste determinanten zijn van innovatie, en Cohen en Levinthal (1990) hadden reeds gevonden dat de interactie tussen intern en extern opgeslagen kennis belangrijk is voor innovatieprestaties. In deze studie hebben we het innovatiemodel van Arnold en Bell (2001) verder ontwikkeld met nadruk op de analyse van de kennisstroom tussen verschillende domeinen (bedrijfsleven, onderzoek & onderwijs en intermediaire organisaties) en institutionele aspecten die van invloed kunnen zijn op kennisverwerving en kennisoverdracht (zoals de marktvraag en de infrastructuur en wet-en regelgeving). Om tot een beter inzicht te komen in de complexiteit van de factoren die verbandhouden met innovatie en bedrijfsprestaties, luidt de eerste onderzoeksvraag:

Onderzoeksvraag 1 (RQ1): wat zijn de belangrijkste drijvende en remmende factoren van een doeltreffend en goed functionerend sectoraal innovatiesysteem in China (hoofdstuk 2) en in Nederland (hoofdstuk 3)?

De studie in hoofdstuk 2 leidde tot de conclusie dat gebrek aan communicatie over en weer en kennisoverdracht tussen verschillende domeinen de innovatie van de groenteveredelingsindustrie in China belemmert. De studie in hoofdstuk 3 leidde tot de conclusie dat het uitstekende innovatie niveau van de groenteveredelingsindustrie in Nederland niet alleen gebaseerd is op uitstekende prestaties binnen elk domein van SIS, maar ook op de goede wisselwerking tussen de verschillende domeinen. Aldus blijkt uit beide studies in China en Nederland het belang van interacties tussen verschillende kennisdomeinen voor innovatie binnen de sector.

In beide landen wordt het belang van innovatie in deze sector erkend. De methoden om innovatie op sectorniveau te stimuleren zijn echter geheel verschillend. De regering speelt in de Chinese groenteveredelingsindustrie meerdere rollen. Publieke organisaties zijn actief als belangrijke actoren in alle drie de relevante domeinen binnen de sector: het business domein, het onderzoek & onderwijs domein en het transitie domein van intermediaire organisaties. Grote gouvernementele investeringen in onderzoeksorganisaties en staatsbedrijven hebben investeringen door particuliere bedrijven ontmoedigd. Daarnaast zijn er slechts een beperkt aantal intermediaire organisaties die gericht zijn op het stimuleren en vereenvoudigen van samenwerking in R&D. Daarom opereert het innovatienetwerk suboptimaal en dit leidt tot een sterk beperkte kennisoverdracht tussen en binnen de verschillende domeinen. In tegenstelling hiermee opereren de actoren in de verschillende domeinen van de Nederlandse groenteveredelingsindustrie vanuit een sterk specialisme in hun domein en werken zij intensief samen met actoren in de andere domeinen. De regering speelt een ondersteunende en faciliterende rol ter bevordering van innovatie door de verschillende actoren binnen hun eigen domein, door middel van gunstig beleid en het stimuleren van initiatieven die samenwerking van actoren afkomstig uit verschillende domeinen bevorderen (zoals Publiek-Private-Samenwerkingsverbanden). Organisaties binnen de verschillende domeinen hebben hun absorptiecapaciteit opgebouwd op basis van kennis die is opgedaan met voorafgaande R&D-investeringen, terwijl innovatienetwerken worden georganiseerd om de kennisoverdracht tussen de verschillende domeinen te bevorderen.

Daarom is de belangrijkste drijvende kracht voor een succesvol innovatiesysteem de specialisatie van de actoren binnen hun eigen domein en de samenwerking met actoren afkomstig uit verschillende domeinen. Beperkingen in kennisoverdracht tussen de domeinen kan worden beschouwd als een van de grootste belemmeringen.

Innovatie op bedrijfs- en projectniveau

Vanwege de technologische en bestuurlijke complexiteit van de ontwikkeling van nieuwe producten zijn bedrijven niet langer in staat alle innovatieactiviteiten zelfstandig te verrichten. In de literatuur over innovatiemanagement is het inmiddels algemeen erkend dat bedrijven zelden alleen innoveren, maar dat zij onderdeel zijn van dichte netwerken van contacten en samenwerkingen met externe innovatie partners, zoals de toeleverende industrie, universiteiten en onderzoeksinstellingen, intermediaire organisaties, consultants, gouvernementele organisaties en zelfs concurrenten (Granstrand et al., 1992; Gemünden et al., 1996 ; Spender, 1996 ; Cobbenhagen, 1999 ; Omta et al., 2002 ; Laursen en Salter, 2006 ; Dodgson et al., 2008b ; Batterink, 2009 ; NSF, 2012). Dergelijke innovatienetwerken bieden bedrijven toegang tot kennis en middelen waarover zij zelf niet beschikken. Echter, kennis is niet vrij beschikbaar en het gaat vaak om impliciete kennis, die zeer context-specifiek kan zijn, en dat vereist dat bedrijven de opnamecapaciteit hebben om de waarde van nieuwe, externe informatie te herkennen, te assimileren, en toe te passen voor commerciële doeleinden. Om dit te bestuderen hebben we het “input-throughput-output model” voor innovatieprocessen geadopteerd en dit model eerst toegepast op bedrijfsniveau. Daarbij hebben we ons geconcentreerd op het interne en externe innovatienetwerk van GVBs en op hun potentiële en gerealiseerde absorptievermogen in het “throughput” stadium wanneer innovatieprocessen hun vorm krijgen. Vervolgens werd de impact van opnamecapaciteit op projectniveau bestudeerd in de vier stadia die in het innovatieproces kunnen worden herkend: acquisitie, assimilatie, transformatie en applicatie. Bijgevolg was de onderzoeksvraag die behandeld werd in hoofdstuk 4 en 5:

Onderzoeksvraag 2 (RQ2): Wat is de rol van het innovatienetwerk en de absorptiecapaciteit van een bedrijf op diens innovatie- en bedrijfsprestaties op bedrijfniveau (hoofdstuk 4) en projectniveau (hoofdstuk 5).

Voor het beantwoorden van onderzoeksvraag 2 op bedrijfsniveau werden (i) empirische gegevens verzameld met behulp van een vragenlijst, die was afgeleid van de Wageningen Innovation Assessment Toolkit (WIAT) en (ii) semi-gestructureerde interviews gehouden met senior managers van 51 GVBs in China. Voor het beantwoorden van onderzoeksvraag 2 op projectniveau werden, met behulp van een tweede WIAT-afgeleide vragenlijst, empirische gegevens verzameld van 68 innovatieprojecten in GVBs in zowel China als Nederland.

Uit de studie beschreven in hoofdstuk 4 kon geconcludeerd worden dat GVBs verbeterde bedrijfsprestaties kunnen bereiken met behulp van twee strategieën. De eerste strategie zet in op het verbeteren van de absorptiecapaciteit waardoor een hoger niveau van innovatie en concurrentiekracht wordt bereikt. De tweede strategie zet in op het verbeteren van het innovatienetwerk om de bedrijfsprestaties te verbeteren. We konden aantonen dat de kwaliteit van het externe netwerk een positief effect heeft op de relatie tussen potentiële absorptiecapaciteit en innovatie output; ook het interne innovatienetwerk had een positieve relatie met innovatie output. Een netwerkstrategie stelt een bedrijf dus in staat om effectief gebruik te maken van externe kennis. Om effectief gebruik te kunnen maken van externe kennis geven wij daarom het advies aan GVBs deze twee strategieën te combineren en dus zowel hun externe netwerk uit te breiden als hun absorptiecapaciteit te verbeteren. In feite vonden we dat snel groeiende jonge GVBs deze gecombineerde strategie al toepassen.

De studie in hoofdstuk 5 leidde tot de conclusie dat er een dynamisch samenspel is van de vier stadia van innovatieprocessen, en dat communicatiemogelijkheden een essentiële rol spelen. Teamcommunicatie bleek belangrijk te zijn in de stadia van kennisverwerving en kennisassimilatie om externe informatie te identificeren, te bespreken en te interpreteren voor gebruik in een innovatieproject. Cross-functionele communicatie was vooral belangrijk in de transformatiefase en de toepassingsfase, waar het helpt om de belemmeringen van de nieuwheid van een innovatieproject te overwinnen. Dit zal vooral gunstig zijn wanneer de productontwikkelingscyclus relatief lang is zoals in de groenteveredelingsindustrie. Cross-functionele communicatie zal relevante functies binnen het bedrijf betrekken bij het innovatieproces, wat nodig is voor de ondersteuning van de ontwikkeling en marketing van nieuwe producten.

De resultaten van deze studie leveren belangrijke bijdragen aan bestaande theorieën. Deze kunnen als volgt worden samengevat:

- Deze studie breidt de “knowledge-based view” theorie verder uit, door verklaringen te bieden voor innovatieprestaties op zowel sector-, bedrijfs- als projectniveau. De innovatietheorie werd tot nu toe alleen op bedrijfsniveau toegepast (Kogut en Zander, 1996; Spender, 1996 ; Blindenbach-Driessen en van den Ende, 2006 ; Dodgson et al., 2008a ; Lopez en Esteves, 2013), en wij hebben dit uitgebreid tot bedrijfs- en project niveau. We gebruikten de SIS benadering om innovatie op sectorniveau te analyseren en de absorptiecapaciteit om innovatieprocessen op projectniveau te analyseren. Het innovatienetwerk en de absorptiecapaciteit werden geanalyseerd op alle drie niveaus van sector, bedrijf en project.

- We hebben een multi-dimensionale meting van potentiële en gerealiseerde absorptiecapaciteit uitgevoerd waarmee empirisch de theoretische bijdrage van Zahra en George (2002) gevalideerd werd. Wij hebben daaraan ook metingen van interne en externe innovatienetwerken toegevoegd, waarmee de studie van Camisón en Forés (2010), die absorptiecapaciteit alleen empirisch hebben bestudeerd, werd uitgebreid. Aldus werd het gecombineerde effect van innovatienetwerk en absorptiecapaciteit op innovatie output gevonden.

- We hebben studies over innovatieprocessen verder uitgebreid naar projectniveau (Borsi en Schubert, 2011; Europese Commissie., 2011 ; ISF, 2011b ; LEI, 2012 ; NSF, 2012) vanuit het perspectief van de absorptiecapaciteit. De belangrijkste factoren die de prestaties van innovatie projecten beïnvloeden werden gevonden door een analyse van de interactie van factoren in de vier stadia van het innovatieproces: acquisitie, assimilatie, transformatie en applicatie. Het bleek dat teamcommunicatie en cross-functionele communicatie belangrijke, maar verschillende, rollen spelen in de verschillende stadia van het innovatieproces op projectniveau.

In het algemeen biedt deze studie meer inzicht in de rol van het innovatienetwerk (Newman, 2010; Omta en Fortuin, 2010 ; Schoubroeck en Kool, 2010) en de absorptiecapaciteit (Pavitt, 2002; Daghfous, 2004) als twee belangrijke parameters van innovatie en bedrijfsprestaties. Het proefschrift beschrijft ook het gecombineerde effect van innovatienetwerk en opnamecapaciteit op innovatie en ondernemerschap prestaties.

Deze studie heeft belangrijke implicaties voor de groenteveredelingsindustrie, dia als volgt kunnen worden samengevat. Overheden wordt geadviseerd zowel specialisatie als samenwerking van verschillende soorten actoren in deze sector aan te moedigen om zo het innovatieniveau binnen deze sector verder te versterken. Het is belangrijk voor bedrijven en organisaties binnen de verschillende domeinen van de groenteveredelingssector om kennis op te bouwen op basis van hun eigen investeringen in R&D, naast het verwerven van externe kennis door samenwerking. Bedrijven moeten gemotiveerd worden te investeren in zowel innovatienetwerken als absorptiecapaciteit omdat een goed netwerk het effect van kennisabsorptie op de innovatie output en op bedrijfsprestaties vergroot. Daarnaast moeten bedrijven intern zowel hun communicatie binnen het projectteam als cross-functionele communicatie stimuleren om te zorgen voor betere projectprestaties. Teamcommunicatie speelt een belangrijke rol in de acquisitie- en assimilatiefase van een innovatieproject en zou het projectteam kunnen helpen om nieuwe ideeën te ontwikkelen en marktpotentieel te identificeren. Cross-functionele communicatie is belangrijk in het stadium van kennistransformatie en -toepassing en zal bijdragen aan de ontwikkeling van verwante functionele capaciteiten die de ontwikkeling en marketing van nieuwe producten ondersteunen.

About the author

Zhen Liu (刘珍) was born in 1984 in the P.R. of China. She obtained her BSc degree and Master degree on Business Administration and Enterprise Management in Huazhong Agricultural University in 2005 and 2008 respectively. Then she joined, as a PhD student, the Management Studies of Wageningen University and Research Centre (WUR) in September 2008 after participating in the Asia Fund project of International Training Center for Horticulture Plant Biology, which is a collaboration of WUR and Huazhong Agricultural University. Her PhD research project is on "Vegetable breeding innovation in China and the Netherlands: a study at sectoral, company and project level". The results of this research are described in the present book. During her PhD study, she also worked as a visiting researcher at Chinese Center of Agricultural Policy (CCAP) of Chinese Academy of Sciences, Institute of Agricultural Economics and Development of Chinese Academy of Agricultural Sciences, WUR China Office. Furthermore, she also has worked as a business developer of Food and Biobased Research of WUR since 2012. She has presented her works in countries in Europe, Asia and North America. Her research interests are in the interdisciplinary areas involving innovation management in international chains and networks, technology extension and transfer, company innovation, strategy management, especially in agricultural and food business.

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Completed Training and Supervision Plan

Name of the activity	Department/Institute	Year	ECTS (=28 hrs)
A. Project related competences			
Organisation of the Agribusiness (BEC-31306)	WUR	2008	6
Entrepreneurship Summer School	DAFNE and University of Wisconsin Madison	2008,2009	3
Workshop 1—Seed and Planting Material: connecting knowledge, opportunities and business between the Netherlands and Asia & Pacific	APSA, Leiden	2008	1
Workshop 2—World Seed Conference	FAO, Rome, Italy	2009	1
'Innovation network and performance of Dutch and Chinese Vegetable Seed Companies'	WASS PhD day	2009	1
'Comparison of Innovation Networks of Dutch and Chinese Vegetable Seed Companies'	WICaNeM, Wageningen	2010	1
'Evolution of Innovation System of the Chinese Vegetable Seed Industry'	Seminar, Wageningen	2011	1
'Experience and Enlightenment of Dutch Agricultural Research and Technology Transfer System'	Bi-Annual Conference of Chinese Overseas-returned Scholars Association, The Hague	2011	1
'Comparison of the Sectoral Innovation System of Dutch and Chinese Vegetable Seed Industry'	VCWI Knowledge and Innovation Forum, Twente University	2012	1
'An Absorptive Capacity Perspective on Innovation in the Dutch and Chines Seed Industry' and 'Drivers and Barriers for Innovation in Chinese and Dutch Seed and Food Companies'	23rd Annual IFAMA World Forum and Symposium, Atlanta, USA	2013	2
B. General research related competences			
WASS Introduction course	WASS	2008	1.5
Information Literacy, including Introduction Endnote	WGS	2008	0.6
Scientific Publishing	WGS	2008	0.3
Research Methodology I: From topic to proposal	WASS	2008	4
Qualitative Data Analysis: Procedures and Strategies (YRM-60806)	WUR	2008	6
Quantitative Data Analysis: Multivariate Techniques (YRM-60306)	WUR	2010	6
Scientific Writing	WGS	2012	1.7
PLS Path Modelling-Introduction & Application	Hamburg University	2011	1
EDEN Doctoral Seminar on Social Network Analysis: Theory and Methods	EIASM	2013	4
TOTAL			**43.1**

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