MSc Thesis (45 ECTS)

How innovative industries emerge and survive in peripheral regions

Master
Innovation Sciences

Supervisor
Prof. dr. M.P. Hekkert

Second reader
Dr. G. Heimeriks

Author
R. M. Hillenius

Date
17-09-2018

Abstract
Within the literature on Regional Innovation System (RIS), previous studies have focussed on successful RISs, but fail to explain how companies can succeed in peripheral regions. This paper explores why some firms locate in regions that do not fulfil the typical requirements of a successful RIS and how they survive in these regions. To this end a case study was performed on the Dutch province Frisia. Three clusters within Frisia were analysed: the High-tech Systems and Manufacturing (HTSM) cluster, the water technology cluster and the dairy/food cluster, using a framework that draws on both the RIS literature and the literature on Technological Innovation Systems (TIS). Specifically, the three clusters are studied in-depth from a system structure and function perspective (typically used for analysing TISs) within the context of a RIS: the province Frisia.

The results form this study show that firms locate in Frisia because of one or several of the following reasons: relatively low production costs compared to metropolitan regions, the presence of sufficiently large supply of MBO schooled labourers, the availability of resources and last financial incentives by the local government. Moreover, the results from the system function analyses provided insight in the minimum requirements that enabled local companies to grow and start clustering. Entrepreneurial activities (F1), knowledge development (F2), market formation (F5) and the availability of resources (F6) were most important in an early stage of regional development, of which only the last was geographically bounded. Knowledge exchange (F3) and guidance of the search process (F4) become increasingly important for the clusters to grow.

This research has two major implications on the RIS literature. First, this study shows the value of analysing the development of RISs from a system structure and function perspective. Doing so provides insight in how the structure of a RIS interacts with the development of its clusters. Second, this study shows how the requirements of firms change as clusters emerge and develop over time. For policy makers this indicates that in early stages of regional development, the chance to create new clusters can be increased by attracting a large company or knowledge institute and identifying and maximising the place surplus of their region. As several companies locate in a region and the needs of companies become more knowledge oriented, a focus on strengthening the structure and dynamics in the RIS becomes more important.

Table of contents

1. Introduction

Over the past three decades policy makers and social scientists have been increasingly interested in the geography of innovation. Following statistics like an uneven distribution of gdp per capita across regions in the world (OECD, 2016), studies in the early 1990's found that innovative activities are often geographically concentrated. In this context the innovation systems (IS) approach started to emerge from evolutionary economics (Kline & Rosenberg, 1986), driven by the limitations of neoclassical economic theory to explain the importance of technological and institutional change for differences in economic growth between countries (Freeman & Soete, 1997).

According to the IS approach, innovation does not take place in isolation; firms are embedded in a broad societal structure of research institutes, industries and institutions, that all contain determinants of technological change (Lundvall, 1992). There have been many definitions of the IS (Lundvall, 1992; Nelson, 1993; Patel & Pavitt, 1994; Metcalfe, 1995; Edquist, 2004), of which the most widely used one is by Freeman (1987) who defines the IS as: *"The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies".* Following, differentiations have been made between the system boundaries of innovation systems each resulting in a different unit of analysis. Most notably are the National IS (Freeman, 1987; Lundvall, 1992), the Technological IS (Carlsson & Stankiewicz, 1991), the Sectoral IS (Breschi & Malerba, 1997) and finally the Regional IS (Cooke et al., 1997).

During the development of this body of literature, some of the most cited studies include studies on successful regional 'clusters' of companies (Porter, 1990), the by now world wide known exemplar Silicon Valley (Saxenian, 1990) and the geographic sources of innovation (Feldman & Florida, 1994). These studies all share the notion that regional agglomeration serves as an optimal setting for the economic development of innovative industries, due to economies of scale, short interaction distances and specialized resources. This has resulted in the addition of a regional dimension in innovation policy by many countries (Asheim et al., 2011; Fritsch & Stephan, 2005; Werker, 2006).

One of the limitations of these studies is that they tend to focus on the most successful regions: *"Much of the existing literature has focused on highly successful RIS and on regions characterized by a prevalence of medium- to high-technology industries"* (Asheim et al., 2011). However, there are also some examples of highly successful start-ups that have thrived in locations where you would not expect them based on RIS literature. In his book Mahroum describes several of these seemingly rare cases, including leading recruitment website 'bayt.com' from Dubai and Skype from Talinn, which he defines as black swan start-ups (Mahroum, 2016). The fact that these companies locate and survive in such a relative vacuum does not follow from the RIS literature. To bridge this literature gap, this paper will focus on the question why (small clusters of) companies locate / survive in regions that do not seem to fulfil the criteria of a successful RIS. The main research questions therefore become:

RQ1: Why do firms locate in regions that do not seem to fulfil the criteria of a successful regional innovation system?

RQ2: How do firms survive in regions that do not seem to fulfil the criteria of a successful regional innovation system?

To answer these questions, a peripheral region with several relatively small clusters of companies that is not known for its innovative performance is chosen as a case study. An interesting region to research in this respect is Frisia, a province in the northern part of the Netherlands. Frisia is mainly known as an agricultural province with a large tourism sector due to its many lakes (Wikipedia, 2017). Furthermore, Frisia does not have a university and the percentage of the workforce with a higher education is around 25% lower compared to the national average (CBS, 2016). Last, the province got assigned a low score on innovative performance compared to other Dutch provinces (ING Economisch Bureau, 2015).

Nevertheless, there are several interesting clusters that you would not expect to be located in Frisia based on RIS literature. For this research we focus on the (technology related) clusters identified by the Frisian province as most important for the economy: the dairy food cluster, the water technology cluster and the HTSM cluster (Provincie Friesland, 2017). Two examples of interesting clusters will be given. First, the water technology cluster, in which over a hundred companies and a dedicated research centre are actively involved (WssTP, 2017). Second, the HTSM (High Tech Systems & Materials) cluster with a company that makes luxury yachts worth multiple hundred million of euros. Both sectors rely on highly specialized technological knowledge for innovation. Given the benefits of a successful RIS, it seems logical that these clusters are located elsewhere.

To this end, a theoretical framework is developed, combining theory on (regional) innovation systems (Lundval, 1992; Cook et al., 1997) and black swan start-ups (Mahroum, 2016). Theoretically this study contributes to the existing literature by increasing the understanding of innovation and knowledge transfer in less successful regional innovation systems, which is still underdeveloped (Asheim et al., 2011). Furthermore this study is the first to apply system functions of the TIS as defined by Hekkert et al. (2007) on a RIS. The system function approach is also used in a novel way, to identify the minimum requirements for regional development. From a practical point of view, this study contributes to shaping innovation policy to stimulate the economic development of less successful regions, about which currently little is known (Fritsch & Slavtchev, 2011). Also, the study provides policy makers and managers with a better understanding of the effect of the RIS on cluster and firm performance, which provides tools to strengthen the RIS from a firm / cluster perspective.

This research is structured as follows. First, the factors that contribute to a successful RIS will be discussed in the theoretical framework. Second, the methodology will be described combining a quantitative approach to sketch the structure of the RIS, and a qualitative approach to gain insight in the functioning of the RIS. Third the three clusters will be discussed in detail, paying attention to the origin and the differences and similarities in the functioning of the clusters. This provides solution approaches on how to change the structure of the RIS as a means to improve the functioning of the RIS. The paper concludes with a discussion on the factors that are key to the development of the RIS.

2. Theory

The theoretical framework is structured as follows. Firstly, an *overview of a RIS* will be given, as a means to understand why companies establish in a certain region that does not fulfil all the required elements of a RIS. How is the theory of RIS generated, what is her background in terms of literature and of what elements does RIS exist? Next the *different types* of (regional) innovation systems will be stress, which give an idea of the state of development of the RIS. A third point of discussion will be the question of when a RIS does not work; which *system functions* have to be fulfilled and which dynamics have to be taken into account. Lastly a different body of literature*, black swan start-ups,* will be explained.

2.1 Regional innovation system

History of RIS

In this paragraph, the RIS theory as developed by Cooke (1992) is explained. The RIS builds on NIS literature (Lundval, 1992), which proved to be an inappropriate tool for policy. This was mainly due to the large differences within NIS's and the number of interactions causing increasing complex relations at the national level (Cooke et al., 1997). Carlsson and Stankiewicz (1995) add to this with a study on the global, national and regional perspective of IS. They argue that the regional perspective provides a better unit of analysis, due to the reduced complexity of the interactions. Consequently, the regional perspective on innovation gained in popularity among scholars. Comparable with the NIS, the RIS is also based on an evolutionary framework that follows the same theoretical notion that innovation does not take place in isolation (Edquist, 2004), but with an emphasis on the role of regional learning processes and institutions (Cooke & Morgan, 1994; Asheim & Isaksen, 1997). Regions can be defined as: *"territories smaller than their state possessing significant supralocal governance capacity and cohesiveness differentiating them from their state and other regions"* (Cooke et al., 1997).

In taking a regional perspective, RIS literature also builds, among others, on the work on clusters (Porter, 1990) and technological infrastructure (Feldman & Florida, 1994), which shall be shortly described. Porter depicts the concentration of innovative activities in space, as regional 'clusters' of companies, in which a cluster is defined as: *"Geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions (for example universities, standards agencies and trade associations) in particular fields that compete but also co-operate"* (Porter, 1998). Porter recognizes five reasons why firms locate in geographic proximity to each other, leading to the existence of clusters: better access to employees and suppliers, access to specialized information, complementarities, access to institutions and public goods and lastly better motivation and measurement (Porter, 1998). In addition, Feldman & Florida (1994) attribute the advantages of a cluster to the technological infrastructure of the region in which it is located. This technological infrastructure is defined as the agglomeration of four dimensions: firms in related industries, academic R&D, industrial R&D and business-service firms (Feldman & Florida, 1994). In short, innovations are not so much the product of individual firms, but the product of knowledge, capabilities, assembled resources and other capabilities that are agglomerated in close geographical proximity to each other (Feldman & Florida, 1994). Hence, a strong technological infrastructure is an important prerequisite for the capacity of a region to innovate. The technological infrastructure forms the basis of a RIS.

Five structural elements of RIS

Cooke et al (1998) describe the RIS as the institutional infrastructure that supports the creation of (new) knowledge and practices through learning and development within the boundaries of a region. The structure of the RIS is build up of five interacting components: the knowledge generation & diffusion subsystem, the knowledge application & exploitation subsystem, interaction through networks, policy and lastly the external political influences (see figure 1). These five components will each be briefly explained.

The first subsystem, knowledge generation and diffusion system is mainly build up of public organizations like research institutes, universities and technology transfer offices (Cooke, 2002). The presence and quality of these institutes determines to a large extent the availability of high quality knowledge production and its diffusion in a region and is therefore seen as an important component of the RIS.

The second subsystem consists of the parties that utilize the knowledge flow from the first subsystem. This knowledge application and exploitation subsystem consists of companies and all kinds of different actors like customers, collaborators, contractors and competitors. This subsystem has a certain overlap with the first subsystem, because larger companies also engage in knowledge creation, especially when they have private R&D laboratories (Cooke, 2002). Furthermore vertical networks exist between companies and their suppliers and horizontal networks exist between collaborators and competitors. The quantity and quality of these relations and the presence of customers, the availability of venture capital and the amount of start-ups and spin-offs are important for this subsystem.

The third important part of the RIS framework is interaction between actors. The interaction between the actors through networks is important to share ideas and learn from each other to turn inventions into innovations that stimulate the economic development of the region (Cooke et al., 1998). Therefore it is important to map these networks and collaborations between actors.

Fourth, regional policy can greatly influence the success of the RIS by adapting the institutional structure to the needs of the industries. The institutional structures make up the ‘rules’ within an IS. There are formal institutions in the form of government-enforced laws and informal institutions, which are more tacit and socially shaped (Hekkert et al., 2011). Primarily the formal institutions can be changed to suit the needs of industries. The amount and quality of the relationships between industry representatives and policy makers is therefore an important prerequisite for exchanging the needs of the industry with the regional government.

Fifth, the RIS is characterized as a highly open system with institutional influences from the NIS, International organizations and other RIS (Cooke, 2002). Since informal institutions are hard to systematically map, they will be neglected in this research.

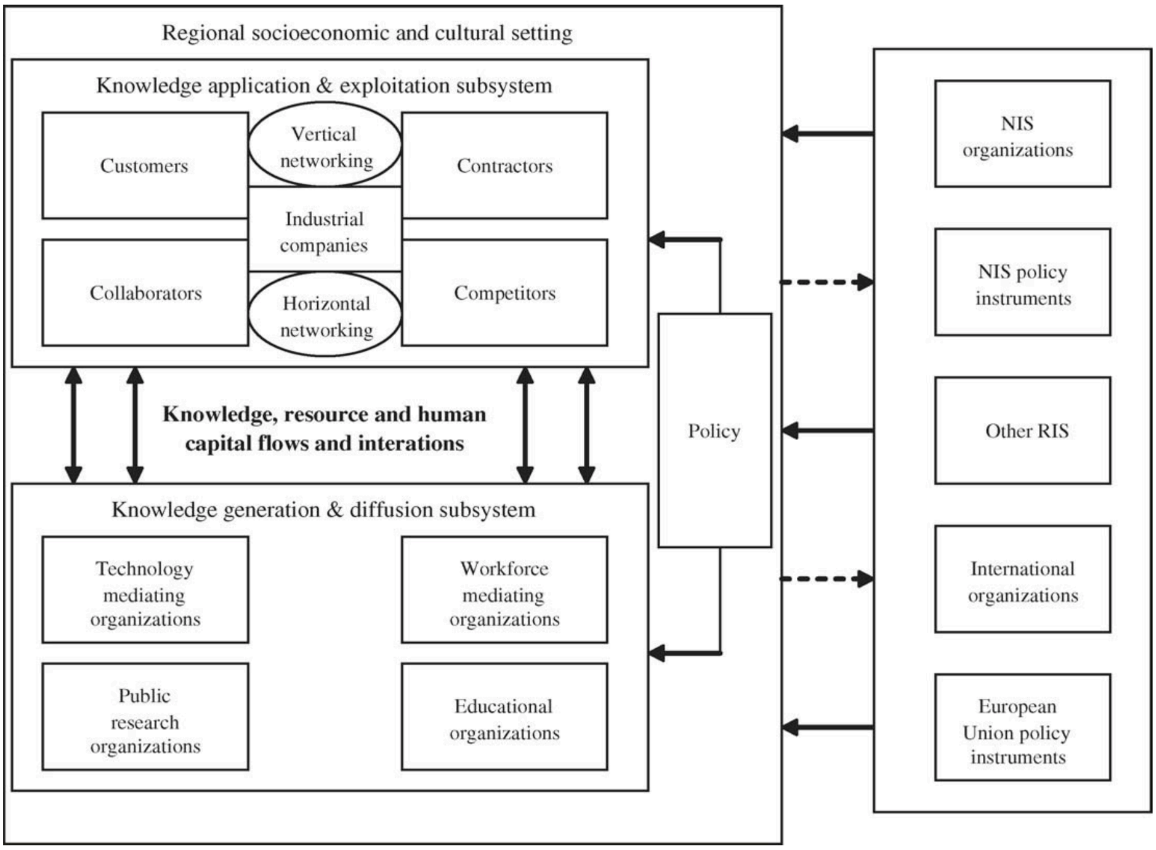

Figure 1: Main structure of regional innovation systems (Tödtling & Trippl, 2005; Cooke, 2002; Autio, 1998).

2.2 Types of RIS

The first paragraph provided a theoretical background and the five elements of RIS. This paragraph stresses the types of RISs as a means to describe the state of development.

A weakness of many studies on RISs is that they do not provide an analysis of the evolution of the innovation system over time (Feldman, 2001). A lack of historical perspective makes it difficult to accurately observe differences in for example institutional setting, leading actors and the kind of governance. This generates a thorough understanding of the state of development of the RIS, thus enabling the most efficient ways to enhance the functioning of the RIS. Looking at the state of development and type of industry, Asheim et al (2011) recognize three dimensions of RISs that are dominant in the literature.

First, is a distinguishment between institutional RIS and entrepreneurial RIS, based on their capacity to develop dynamic high-tech clusters (Cooke, 2002). Cooke argues that the institutional RIS relies on institutional support and is most useful in the development of more traditional sectors. On the other hand, the dynamics in an entrepreneurial RIS can be found in the support of 'intense processes of knowledge exploitation', like local entrepreneurship-, venture capital-, incubators- and scientific excellence, which is more beneficial for high-tech industries.

Second, RISs can be differentiated based on different kinds of knowledge bases (analytical, synthetic, symbolic) and their accompanying dominant industry (Asheim et al., 2007). A RIS with an analytical knowledge base mainly relies on scientific and often codified knowledge, exchanged between typically high-tech firms and universities. A RIS with a synthetic knowledge base is characterized by the application or combination of existing often ‘tacit’ knowledge, mainly seen in specialized production and shipbuilding industries. Lastly, a RIS with a symbolic knowledge refers to aesthetic rather than cognitive knowledge, associated with the creative industry.

Third, RISs can be differentiated based on their problems and barriers (organizational thinness, lock-in, fragmentation), resulting in respectively peripheral, old industrial and metropolitan RISs (Tödtling & Trippl, 2005). Peripheral RISs show a dominance of SME’s with a low level of R&D and product innovation, and is characterized as organizational thinness, due to a lack of dynamic clusters and support organizations. Old industrial RISs show a dominance of large firms with mature technological trajectories, this often leads to a lock-in of the RIS, resulting in a loss of its innovative capabilities. Metropolitan RISs show a dominance of large high-tech firms with large R&D departments, but run the risk of fragmentation, caused by a lack of networks and interactive learning.

As already stressed shortly, there is knowledge of the optimal conditions for a successful RIS. However, it can be concluded that there is no ‘one size fits all’ model of RIS, due to the differences in their nature, governance and performance. The previously discussed types of RIS can be used to classify its state of development.

2.3 System functions

The previous two paragraphs provided insight in the underlying structure of RIS, state of development and the heterogeneity of RIS. However, innovation system analysis based only on the structure of the IS, has proven insufficient (Hekkert et al., 2007). The structure alone does not provide enough insight to assess whether a RIS is successful. For that reason, this paragraph will focus on the dynamics in ISs, allowing measuring differences in performance among ISs (Jacobsson & Bergek, 2004). These dynamics can be explained using ‘system functions’, which are processes that can be seen as the key determinants of innovative performance of an IS (Bergek, 2002).

Many studies have been done on the basic functions that can be identified in an IS (among others: Bergek, 2002; Carlsson & Jacobsson, 2004; Edquist, 2004; Hekkert et al., 2007). However there is much overlap between the different functions identified in the literature (Johnson, 2001). This study is based on the set of system functions (see figure 2) as defined by Hekkert et al., (2007), which has gone through extensive empirical validation and corresponds well with the relevant processes in IS (Suurs & Hekkert, 2005; Negro et al., 2006). While originally developed for a TIS analysis, there is no reason why the same set of system functions should not suffice for a RIS analysis. Though, for a region the dynamics become more complex and incorporate multiple technological backgrounds.

#	Function name	Description of system function
F1	Entrepreneurial activities	Entrepreneurs are at the basis of the innovation system. These risk-takers perform commercial experiments and see and exploit business opportunities.
F2	Knowledge development	Learning is important for the development of innovations. It can take place in the form of classical R&D projects, but also learning by doing is important.
F3	Knowledge diffusion in networks	The typical organizational structure of an emergent innovation.
F4	Guidance of the search	A selection process is needed for a convergent development in the IS. It consists of policy aims and the outcome of technical and economical studies and the expectations about technological options.
F5	Market formation	New technologies are often unable to beat the existing technology. For the stimulation of innovation the creation of niche markets is important.
F6	Resource mobilisation	Financial, material and human factors are necessary for the development of a IS. Investments can come from venture capitalists or the government.
F7	Creation of legitimacy / counteract resistance to change	The development of a new technology often encounters resistance from the current socio-technical regime. A lobby to generate support for the technology is necessary.

Figure 2: Functions of the IS (Meelen & Farla, 2013; based on Hekkert et al., 2007).

In a successful IS the different structural components are well aligned. The system functions are the processes that need to be fulfilled to facilitate a successful system in which new products can reach the market. Therefore, the seven system functions are used to create a dynamic picture and analyse the functioning of the RIS.

2.4 Black Swan Start-ups

The first part of the theoretical framework stipulated the framework conditions from the RIS literature that make up a successful RIS. However, there are plenty of technology companies that have been able to become very successful in regions lacking many of the framework conditions from the RIS. Some examples include leading recruitment website 'bayt.com' from Dubai and Skype from Talinn. Both places are not known to have a vibrant RIS. In a recent study on a number of technology start-ups around the world that have thrived against all odds in unlikely places, these companies are referred to as 'black swan start-ups' (Mahroum, 2016). Seemingly, companies located outside technology hubs can also stand out.

According to Mahroum (2016), entrepreneurs who are able to leverage the 'place surplus' of the region in which they are located achieve the best results, in which place surplus is defined as: *'the extra benefits that an individual or an organisation derives from being in a particular place'* (Mahroum, 2016). Based on an extensive literature review, Mahroum then identifies 15 factors divided among 5 categories that make up the place surplus (see figure 3).

Cost	Calibre	Convenience	Creative destruction	Community
Low cost production	Infrastructure	Access to global networks	Entrepreneurial university	Open and collaborative social and professional networks
Government support	Access to highly skilled talent	Business-friendly regulatory environment	Culture of risk-taking	Anchor firms
	Flexible specialisation	Highly skilled entrepreneurial immigrants		
	Knowledgebase	Risk capital Attractive lifestyle		

Figure 3: 15 factors that contribute to 'place surplus' (Mahroum, 2016).

Where this paper not only looks at technology start-ups, it is still interesting to see what lessons we can learn from Mahroum (2016). Based on the case studies on 'black-swan' companies, all entrepreneurs followed a strategy in which they maximised the place surplus of their respective region. The factors access to global networks, business-friendly regulatory environment, anchor firms, risk capital, culture of risk-taking and flexible specialisation were more often not present than they were present. The factors government support, access to highly skilled talent, attractive lifestyle, infrastructure, knowledgebase and highly skilled entrepreneurial immigrants where not deemed critical for success, although they were present in more or less extent in the cases. It then follows that the factors open and collaborative social and professional networks, low cost production and entrepreneurial university were critical to success (Mahroum, 2016).

By reaching out globally, entrepreneurs compensated for factors that they could not get locally. Therefore, regional policymakers and entrepreneurs do not need to copy the Silicon Valley formula in order to bring forth successful companies. Instead they should create possibilities to reach out to other companies, stakeholders and venture capitalists by organising conferences and other platforms. Furthermore the place surplus of the region in which they are located should be exploited to its full extent (Mahroum, 2016).

3. Methodology

3.1 Research design

The aim of this study is to broaden the understanding of why (small clusters of) companies locate / survive in regions that do not seem to fulfil the criteria of a successful RIS. Therefore, this study has an explanatory function (Oost, 2003). Due to the complexity and the amount of factors that influence the dynamics in a RIS, a single-case study design has been adopted. This allows for the combination of both a quantitative as a qualitative approach, contributing to the amount of detail needed for an in depth investigation of the dynamics in a RIS (Bryman, 2012).

As a method for analysis, the technological innovation system manual (Hekkert et al., 2011) was used to structure the data. This approach consists of five steps as explained in the previous chapter: a structural analysis (1), determining the state of development (2), describing system functions (3), determining system failures (4) and determining which factors are essential within and outside the region. Since existing theory is tested on a new case, this study is based on deductive reasoning (Bryman, 2012).

3.2 Case description

The Dutch province Frisia was selected for the case study for several reasons. First, because of its relatively large make-industry, resulting in over 99% of the companies being SME's (KVK, 2017). Furthermore, for Dutch standards Frisia performs in the lowest 25% of the provinces based on innovative performance (ING Economisch Bureau, 2015). Also, Frisia does not have a university, translating to the relatively low percentage of the workforce with a higher education, which is with 25,9% well below the national average of 34,4% (CBS, 2017). Last, based on average income, Frisia scores last of all Dutch provinces (CBS, 2017). These facts are all indicators that Frisia is lagging behind compared to the rest of the Netherlands.

3.3 data collection and analysis

The case study consisted of a structural and a functional analysis. The province Frisia was chosen because it looks like a somewhat empty province at first sight. To gain some more insight in the structural elements of the province, first a desk-research was conducted to construct a picture of the actors that make up the RIS. The structural analysis is based on a large number of reports and quantitative data sources like patents, scientific publications and subsidies. After the structural analysis, a functional analysis was conducted as a means to address the performance of the RIS. To this end, 16 semi-structured interviews have been conducted with key actors from the innovation system. The fundamental difference with the structural analysis is that the system functions provide a more evaluative character (Hekkert et al., 2011). This approach allows getting insight in the dynamics of the RIS of an economic lagging region.

3.3.1 Quantitative data collection

Several quantitative data sources have been used in the structural analysis; patents, scientific publications, subsidy projects and chamber of commerce data. The patent data can be downloaded from the OECD REGPAT database. This dataset covers patent applications filed to the EPO and under the Patent Co-operation Treaty (PCT) from 1977-2012 (OECD, REGPAT database, February 2016). This database was chosen, because the data is regionalised, making it possible to only select patents filed in Frisia.

The scientific publication data was downloaded through Scopus using the names of organizations that could generate scientific knowledge. The subsidy projects can be downloaded from the website of the Netherlands Enterprise Agency (RVO, 2017). This dataset contains all innovation related governmental subsidies from 2006-2016, including subsidies from the European Union. Lastly data from the chamber of commerce is used to identify the largest companies in Frisia (KVK, 2017).

3.3.1.1 Patent data collection and analysis

Patent data was used as an indicator for R&D activity and the knowledge base of the region. The patent data from the OECD REGPAT database is already available at the right level of aggregation, the province of Frisia and consists of 827 patent applications. To identify the firms who hold the most patents, the patent database was manually screened to merge identical firms that are registered as different applicants. The EPO classifies patents into different IPC classes. To identify the different technology classes that are most used in Frisia, the IPC classes of all patents are reduced to a 3-digit level. The 3-digit level was chosen because it gives more insight in the different technology classes, while not resulting in such a large amount of different classes that the data is not generalizable anymore. It must be noted that patents can get several IPC classes, in this case on average around 3-4 IPC classes per patent. Another critical point is that firms that are not only located in Frisia may file their patents at another location, resulting in the patents not showing up in these statistics.

3.3.1.2 Scientific publication data collection and analysis

Scientific publications can serve as an indicator for the academic R&D concentrations of a region. Therefore the different institutions that might generate scientific knowledge are identified and checked in Scopus. Scopus data allows co-author analysis, so the most important connections of the Frisian knowledge gathering institutions can be identified. It must be noted that Frisia does not have a university, but polytechnic schools, which greatly limits the amount of scientific output. Frisia however does have knowledge institutions.

3.3.1.3 Subsidy data collection and analysis

Subsidy data is an indicator of the amount of innovation projects that a region undertakes. The dataset from the Netherlands Enterprise Agency covers all subsidy projects in Europe, but does not break the data down further that the national level. To identify the subsidies that can be attributed to Frisia, first all subsidies that have a tag ‘NL’ were selected. The resulting dataset contains a geolocation of the assignee, which are converted into postcodes using a self-made script that is then attributed to the right province. To help structure the results, all subsidies were manually attributed to one of 120 technology classes as used by the Netherlands Enterprise Agency (RVO, 2017). In the data analysis it becomes clear how much subsidy has been granted and for what kind of projects.

3.3.2 Qualitative data collection and analysis

In order to acquire more in depth information about the RIS of Frisia, 16 semi-structured interviews have been conducted with experts of innovative companies within the three sectors. Six experts have been interviewed from the HTSM cluster and five each for the water technology and the dairy/food cluster. The interview questions were directly derived from the system functions from an innovation system (see appendix 1). Also some experts were asked to clarify notable data points from the different quantitative analysis.

The organizations are chosen based on size, revenue, knowledge, network position, subsidy request or membership of a network organization (see appendix 2). The respondents have been identified using a purposive sampling strategy, based on a desktop search and referrals from other stakeholders (Bryman, 2012). To ensure theoretical saturation, the sample includes multiple actors per cluster (Bryman, 2012). Furthermore, to increase the validity of this study, the respondents are all high representatives of their respective actor group who are deeply embedded in their respective field.

First the Maritime industry was treated as a distinctive cluster, but it was later decided to incorporate the industry in the HTSM cluster. This was decided due to the fact that there was limited quantitative data on the sector available and a lack of interest from the largest and most innovative ship building companies to cooperate with the research. Also, the two companies first classified as part of the Maritime industry that did want to cooperate were both member of the Innovation Cluster Drachten (a network organization active in the HTSM cluster).

Following Hekkert et al (2011) all experts were asked to grade the seven system functions on a 5-point likert scale (1: very weak, 5: very strong). The average score per sector gave an indication to identify the strongest system functions and the largest system barriers. All interviews are recorded and transcribed [1]. For the analysis all interviews have been coded using NVIVO to identify patterns. A list of the names of the experts has not been included to protect their anonymity. For this reason it was also decided not to provide a description of their background and refer to individual experts as for instance ‘expert 1’, as experts in the field can otherwise deduce their identity.

[1] The transcripts can be requested by contacting the researcher at: r.m.hillenius@uu.nl

4. Results

4.1 An overview of the province Frisia

In the first part of the analysis a short overview of Frisia will be given based on the geographic position of the clusters and some socio-economic characteristics. The latter consists of three topics: characteristics of the labour force, export and R&D expenditures.

First, the geographic locations of the main clusters in Frisia will be discussed. Figure 4 shows a map of the province, additional information on the largest companies of every cluster and their location can be found in appendix 3. The HTSM cluster is mainly located in the southeast part of Frisia around Drachten and Heerenveen. The water technology mainly consists of relatively small companies, with knowledge institution Wetsus in the Frisian capital, Leeuwarden, as its centre. The largest and oldest water technology companies like Paques and Landustrie are located in the southwest part of Frisia. Last the dairy/food cluster is spread all throughout the province with most dairy farms located in southwest part of Frisia. The food processing companies are located throughout Frisia.

Figure 4: The province Frisia (Kaarten & Atlassen, 2017).

During the analysis of the Frisian demography, three things stood out (see appendix 4). First, there are relatively few residents in the age group 20-30 year (appendix 4, figure 8). This can be explained by the absence of a University in Frisia, forcing students who want to attend to university out of the province to complete their education. This leads to the second point. Frisia has been struggling with a migration deficit out of Frisia between 2000-2015 (appendix 4, figure 9). It seems that the residents who left Frisia to complete their education, often do not return to the province after they graduated from university. The exception from this trend is the year 2016 where there was a small migration surplus of people moving to Friesland. This can be attributed to the introduction of the feudal system for students in 2015, resulting in more students who travel from their parental home to university. In addition, the migration of people without a Dutch nationality to Frisia increased in 2016 (Fries Sociaal Planbureau, 2017). Third, the baby boom generation is clearly visible in the population pyramid, with an average age of 65 year (appendix 4, figure 8). Therefore it can be concluded that the Frisian labour force is relatively small compared to the amount of senior citizens.

Looking at the labour force, the lower and medium educational levels are overrepresented (see appendix 5). Moreover, unlike the trend in the rest of the Netherlands, the size of the higher educated labour force is diminishing (appendix 5, table 12). The unemployment rate in Frisia has decreased slightly, in accordance to the trend in the Netherlands. However, southwest Frisia is the only Frisian region with an unemployment rate under the Dutch average (appendix 5, table 13). Finally, the rate of declared bankruptcy has decreased as well, which is in alignment with the reduced rate of unemployment (appendix 5, table 14).

Following, some data on the export of Frisian goods will be discussed. The export of goods is good for 21% of the Frisian economy. This represents a total value of almost 5 billion Euro in 2014, around 85% of which is generated by SME's (CBS, 2014). This seems like a lot, but the total export value of Frisia, Drenthe, Flevoland and Zealand combined is a mere 7% of the total export value of the Netherlands (appendix 6, figure 10). Compared to other provinces in the Netherlands, the export value per inhabitant is €4175 in 2014, the lowest number of all provinces (CBS, 2014). This information is in line with a recent quote of Frisian politician Sander de Rouwe in the Leeuwarder Newspaper on 14 January: *"we have a nice product, but it never changes en rarely crosses the border"* (Leeuwarder Courant, 2017).

However, the situation seems more complex than de Rouwe states. When looking at the export percentage to non-EU countries for instance, Frisia scores higher than all other Dutch provinces with around 45% of its total export in 2014 (appendix 6, figure 11). The majority of the export consists of food and beverages, machinery and transport equipment, indicating that these Frisian sectors are very internationally orientated (appendix 6, figure 12).

Lastly, a short overview of R&D expenditures per capita (sum loan costs and other costs) based on WBSO data will be given. The WBSO is an R&D tax credit, provided by the Dutch Ministry of Economic Affairs. This analysis showed a remarkable fact. Compared with all Dutch COROP regions (a division of the Netherlands in 40 regions, used for analytical purposes) southeast Frisia is placed at number 6 out of 40 COROP areas regarding the relative amount of companies that invests in R&D (appendix 7, table 18). All other COROP regions in the top 6 accommodate a university. The WBSO data cannot be analysed in more detail due to confidentiality agreements, but seems largely attributable to the HTSM sector in the region, which is good for 100 million R&D expenses annually in Drachten alone (Link Magazine, 2016). However, this region did not receive the most subsidy projects or patents (see appendix 7 and 8). A possible explanation for the relatively low amount of money spent on subsidy projects is that the cluster is already well developed to the extent that it doesn't need subsidies. With regard to patents the difference could be caused by the fact that large companies submit their patents at their headquarters (e.g. Philips) and therefore do not appear in the statistics for Frisia.

In the next paragraphs the three clusters are discussed in more detail. Each paragraph follows the same structure. First the activities that take place in the cluster are shortly described. Second, the origin of the cluster in Frisia is explained. Third, the reasons why companies want to stay in Frisia are discussed. Last, the most notable results from the functional analysis are presented. It is argued that the reasons to locate and stay located in Frisia change as the companies grow and start to organize themselves in clusters.

4.2 HTSM cluster

HTSM can be split up in nine industrial sectors: automotive, materials production, aerospace, security, medical, energy, professional and consumer products, maritime and civil (RVO, 2017). Within Frisia most companies in HTSM are active in producing professional and consumer products and the maritime sector and are mostly located in the southeast part of Frisia. The HTSM cluster houses 25 companies with over a hundred employees, making it the cluster with most large companies in Frisia, together with the dairy/food cluster (see appendix 3, table 9). Some examples of companies are (1) Philips who develops and produces products like vacuum cleaners, shavers, trimmers and wake-up lights; (2) Stertil, world market leader in heavy-duty vehicle lifts; (3) Whisper Power who create silent and vibration-free generators and electrical systems (4) and last Accell where bikes and fitness apparatus are produced.

4.2.1 Why HTSM companies located in Frisia

The largest company in the sector is Philips in Drachten, which is the only remaining location of Philips in the Northern part of the Netherlands (Smallingerland, 2017). It is also one of the older companies in southeast Frisia, which greatly contributed to the rise of the HTSM sector in the province. Philips Drachten provides a job to around 2000 employees, of which about 700 are active in R&D for product development (Link magazine, 2016). Partly due to the increasing demand for technical schooled employees and materials from Philips, the southeast part of Frisia has grown into an interesting place to locate for HTSM companies.

During the interviews, three reasons were named why the companies were located in Frisia. First, several companies (among which all companies that are a branch location) chose Frisia due to relatively low production costs compared more metropolitan regions. Second, the companies all valued the availability sufficiently educated MBO schooled labours, as they all produce their products within the province. Last, two companies also indicated that tax incentives provided by the local government contributed to the final decision to locate in Frisia, in addition to the other two factors.

4.2.2 Why HTSM companies stay in Frisia

The representatives of the companies that were founded in the province all valued the history of their company within the province and feel connect with the Frisian culture. This, alongside the fact that these companies also had most or all of their assets within the province was the most important factor to stay within the province.

The representatives of branch companies with their headquarter located elsewhere also valued the history of their company within the province. They also named that their company was important for the local community, due to the large amount of jobs they provide. However, since they are a branch organisation, they always have to perform above average or risk being relocated to cut costs. The representatives indicated that this fact above all motivated them to increase their efforts to perform as well as they can. This included cooperating with other companies in the region. As the HTSM cluster develops, the quality of the RIS becomes increasingly important for companies to stay located in Frisia.

4.2.3 Regional Innovation System HTSM

Entrepreneurial activity

Since 2013 a couple of companies within the HTSM cluster have united themselves by creating a cluster organisation, named Innovationcluster Drachten (ICD). The ICD started because of a mutual need of its members to boost the visibility of their companies in the region. Their main goal is to interest and connect talent of within and outside the region, next to the sharing of knowledge and the creation of value-chain. Focus areas of the ICD include 3D metal printing, remote sensoring & big data, robotics, visual intelligence and all-electric propulsion, also regarded to as the 'big 5' of the Northern Dutch high-tech industry (Link magazine, 2016).

The first thing that became clear during the interviews is that the companies focus on Northern part of the Netherlands, instead of just the province Frisia. This manifests itself for example in one of the conditions to become member of the ICD, which is that the company has to be located within an hour drive of Drachten. This automatically includes companies of Groningen and Drenthe. The fifteen member companies of the ICD together house 3100 employees, under which a little over 1000 employees are directly involved in R&D. Although this is reflected in the amount of requested patents in the region, there are still a lot of prominent companies not showing up in the statistics (see appendix 8, table 20). This is not caused by a lack of patent applications from these companies, but by the fact that all patents of a company are often filed at it's headquarter and more than half of the large companies does not have their headquarter in Frisia (e.g. Philips). Nonetheless, when looking at the average R&D loan costs per head of the population, southeast Frisia occupies the 6th place of the 40 COROP areas of the Netherlands (see appendix 7, table 18).

Guidance of the search

The ICD constitutes a clear vision, formulated by the joined companies and the local government. Some of the prerequisites to become a member of the ICD are for example that the company has an international orientation, creates physical products and does not compete with other ICD members. So far, this goal has been proven very effective. The experts of the joined companies are without exception very enthusiastic about their membership and the accompanying advantages. For instance, all the respondents stated that their cluster is clearly visible in North Netherlands, which influences the attraction of talent positively. Next to that, all the respondents noted a shared 3D-metalprinter, which is financed and used together. This investment would have been practically impossible for one of the companies alone.

Knowledge diffusion in networks

Collaboration mainly takes place on themes that are relevant for companies within the cluster, mostly cross sectoral. The aim of ICD is to increase the likelihood of chance in innovation, by making connections between its members (Link magazine, 2016). In this line events are organized to visit member companies and get new ideas. An important element of this success formula is that the affiliated companies are not competitors, to stimulate cooperation instead of competition within the ICD.

Nonetheless all of the experts agree that there could be even more collaboration. The function knowledge diffusion in networks had the lowest score with an average score of 3.1. Although the knowledge diffusion within the cluster has improved quite a bit compared to the knowledge diffusion before the ICD existed, there is room for improvement for (smaller) companies who are not involved in the ICD or are not located in Northern part of the

Netherlands. Therefore, the available knowledge is not accessible for SME's that are not a member of the cluster.

Knowledge development & resource mobilisation
Another point of improvement is the knowledge development and availability of technically educated employees. The experts note that there are several initiatives throughout different education levels to enthuse young people for technical professions. However, it does take some time before the benefits of these efforts can be observed. Next to these initiatives, experts also noted on-going discussions to get the RUG to offer an educational program for mechanical engineering. Lastly, there are programs to stimulate MBO electronica students to step up a level and start an HBO education program with an orientation on mechatronics.

Market formation
The companies unanimously agree on the fact that there is enough market size within and outside of the Netherlands. This system function has gotten the highest score of the experts together with the system function guidance of the search. To conclude the HTSM sector seems well organized, but emphasis should now be given to further facilitating smaller companies in the sector and start-ups.

To conclude, the HTSM sector in Frisia is well organized. The knowledge generation & diffusion and the knowledge application & exploitation subsystem are well developed. This also becomes apparent from the evaluation of the system functions of the RIS, which is very well balanced (see figure 5). Large HTSM companies once located in Frisia due to a combination of low production costs, a sufficient supply of MBO schooled labourers and tax incentives from the regional government. However, as the companies grow in size and number, they increasingly start form horizontal networks and behave like a sector with accompanying benefits.

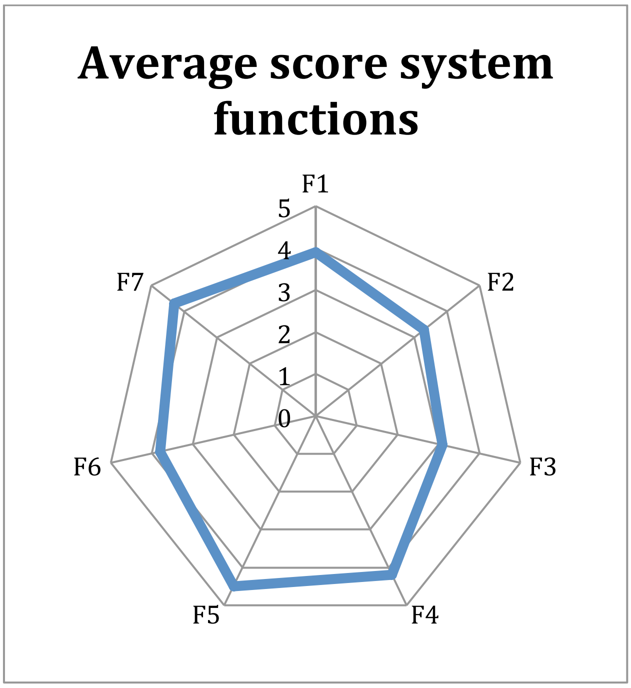

Figure 5: average score system functions by experts HTSM.

4.3 Water technology

The water technology cluster in Frisia is characterized by many relatively small, but highly specialized and knowledge intensive companies (see appendix 3, table 11). The cluster has long been dominated by the widely known and exemplar company Paques. Paques produces anaerobic water purification systems since 1981, that facilitate the re-use of water, whilst producing bio-gas from the wastewater. A more recent but promising company is RedStack, which is developing the reverse electro dialysis technology, to generate electricity through osmosis. A last example is Aqana, a company started by former employees of Paques with a focus on purifying many different wastewater streams using anaerobic bacteria.

4.3.1 Why water technology companies locate in Frisia

The origin of the water technology cluster in Frisia can largely be attributed to the company Paques. The entrepreneur Joost Paques was looking for new business in the 1970s and came in contact with a professor who had a new technology for industrial water purification. Around the same time regulations for industry regarding wastewater treatment became increasingly strict. Paques took his chance and entered the water technology field. Since then several other companies also located in Frisia, often as a spin off from Paques. Most notable is the establishment of knowledge institute Wetsus in 2003.

Ever since the establishment of knowledge institute Wetsus in 2003, the cluster has seen a strong growth rate when looking at the amount of water technology companies (Wetsus, 2017). It is clear though that Paques still holds a central position in the water technology cluster in Frisia. Apart from being the largest water technology company in Frisia in terms of employees, patents and revenue, Wetsus also originated from Paques, as it had the need for more knowledge production in the area of process technology. When this initiative was set into motion, it became apparent that most of the water technology companies in the Netherlands were placed in Frisia and the eastern part of the Netherlands (de Achterhoek). The decision was then made to establish Wetsus in Frisia.

4.3.2 Why water technology companies stay in Frisia

Since the arrival of Wetsus, 200 doctoral students have been facilitated, 79 patents were filed, 30 spin-offs started and 104 companies got a member of Wetsus (see appendix 9). The success of Wetsus can be attributed to the fact that it acts as the centre for an open consortium, in which public as well as the private participating parties decide together on the research agenda and get insight in the results, in exchange for the payment of their membership. Hereupon the doctoral students, whose supervisors are connected to different universities all over the world, conduct the research. In this way, the knowledge of around 55 professors is assembled in Wetsus (Wetsus, 2017). This results in an interesting area to locate for water technology companies.

4.3.3 Regional Innovation System water technology

Knowledge development

Because of the constant supply of new and relevant knowledge by Wetsus, the water technology companies have access to up-to-date and high quality knowledge. Additionally Wetsus provides a constant flood of doctoral students, who for the greater part, stay to work at one of the companies that are connected to Wetsus after finishing their PhD's. The high-quality technological knowledge that is developed and applied in the water technology cluster is clearly visible in the filed patents (see appendix 8, table 19). This results in a good score for the system function knowledge development, which has the highest score on this system function for all of the Frisian clusters with a 4.4 (see figure 6).

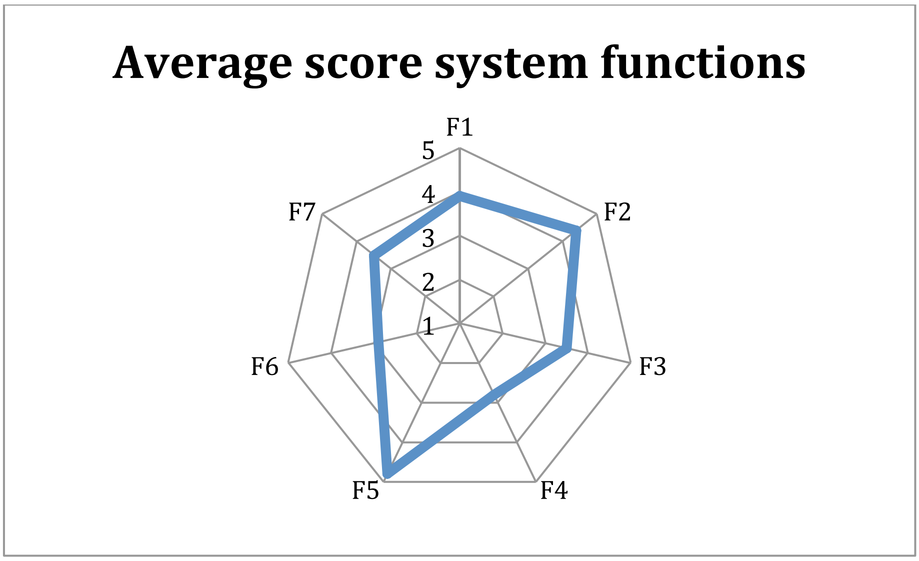

Figure 6: Average score system functions by five experts from the sector.

Guidance of the search

The water technology cluster also contains a network organisation; the Water Alliance. The Water Alliance is a collaboration between the government, knowledge institutions and companies with the aim to shape a European water technology hub in the Netherlands. Over a hundred companies joined the Water Alliance so far. Although the vision of the Water Alliance is known and shared with Wetsus, it seems like the vision of is not sufficiently known or shared with the respondents, who scored the system function guidance of the search with a 2.8. As a part of the aim of the Water Alliance, the R&D director of Wetsus, Cees Buisman, expressed a goal to produce 20-40 companies like Paques with revenues of 50-100 million each from the cluster. However, despite the constant grow of Wetsus and the water technology cluster, it seems that not a single water technology company has come close to this (see appendix 3 table 11).

Market formation

It can however not be blamed on a lack of market potential. The water technology cluster in the North of the Netherlands had a revenue of about 700 million with an added value of approximately 400 million in 2011. This gave the cluster a share of 1,5% in the Frisian economy (bbo grontmij, 2012). Unfortunately there are no more recent statistics known about the share of the cluster in the Frisian economy, although one of the experts did mention that a new report about the water technology cluster was currently being made. Respondents do state that the substantial and still growing market potential for water technology worldwide. For example, the report of Wetsus makes clear that the market for water technology has a worldwide value of 500 billion and a yearly growth of 10%. With an average score of 4,8 the respondents rate the system function market development as the highest rated system function.

Resource mobilization
The market chances in the water technology do not go unnoticed at the government, which can be seen in the granted innovation subsidies for different companies in the cluster (see appendix 7, table 15). However, all respondents note that mainly small companies experience difficulties in accessing the subsidy possibilities, because of the involved application procedure. This is problematic, due to the fact that most of companies active in the water technology sector in Frisia are relatively small (see appendix 3, table 11).

In addition, there is also a shortage of seed-capital, with typical amounts till a total of around 200.000 Euro that could enhance the transformation of inventions from Wetsus into innovations. The limited availability of risk capital seems to be a shared problem within the cluster, although the Water Alliance does facilitate network events at which companies can meet potential investors. In this way some companies have been able to get access to work capital through alliances. For instance, the interview with the company Aqana made clear that the company entered a partnership with a foreign company to get access to work capital. As both risk capital, as subsidies are difficult to acquire for start-ups, respondents express a need for more financial support for start-ups. These reasons could explain the relatively large amount of small companies in this cluster (see appendix 3, table 11).

To conclude, the water technology cluster in Frisia has an international character and shows a constant growth in knowledge production and new firms since the establishment of Wetsus in 2003. Where the cluster was more in need of knowledge in the area of process technology fifteen years ago, this need shifted to a demand for more entrepreneurial spirit and the possibilities to commercialise the available knowledge. Therefore the knowledge generation and diffusion subsystem is well developed, but the knowledge application & exploitation subsystem is underdeveloped. Multiple respondents state that the cluster should increase its visibility within the Netherlands, because Frisia is still displayed too often as a traditional and conservative province, instead of an innovative entrepreneurial province.

4.4 Dairy / food

The dairy/food cluster traditionally has a large share in the Frisian economy. To put this in perspective, 31% of the total Frisian export value of around 5 billion euro is based on the production of food related products (CBS, 2017). The dairy/food cluster consists of several large companies who process milk into different dairy products (see appendix 3, table 10). The largest company is FrieslandCampina who has several large factories in the province producing cheese, butter and other consumer products. Another example is, A-ware who also produces cheese and is located in Heerenveen. Besides the large amount of companies producing dairy based consumer goods, there are also some companies active in food technology. An example is CSK food enrichment, which specializes in delivering the right impact on taste and texture for cheese makers. Alongside those companies, the cluster encompasses big dairy farms, of which the greater part (500 dairy farms) is located in the southwest part of Frisia (ING, 2017).

4.4.1 Why dairy/food companies locate in Frisia

During the interviews, one main reason was named why the companies were located in Frisia. The soil type in large parts of the province is beneficial dairy farms. Consequently, the large number of dairy farms is also the main reason for the presence of multiple large dairy-processing companies. By positioning close to the production, these companies can keep their transportation costs low.

4.4.2 Why dairy/food companies stay in Frisia

The most important reason for companies in the dairy/food sector to stay located in Frisia, is the continuing supply of milk from dairy farms. If the supply diminishes, the province also loses its attraction to dairy food processing companies. For this reason several experts suggested to invest more in food technology to be less dependent on fluctuations in the milk price. However, the large dairy companies that participated in this research all had their R&D laboratories located in Wageningen. So whereas the water technology cluster and the HTSM cluster centralized their R&D departments within Frisia, the opposite is true for the dairy cluster. The generated knowledge of the R&D is put into practice in the processing factories, which are located in various places in Frisia (The exception here is the company Huhtamaki located in Franeker, which produces egg-boxes and has approximately 50 employees working in R&D). Seemingly the absence of a university in Frisia, prompts the companies to locate their R&D departments outside the province. Therefore the RIS should be made more attractive in order for companies to locate their R&D departments within the province.

4.4.3 Regional Innovation System dairy/food

Knowledge development

In this line, an innovation centre for food technology has been announced at the MBO Life Sciences and Van Hall Larenstein; the Food Application Center for Technology (FACT). The next four years will be dedicated to the set up of the location, its start and promotion with a joined investment of 5 million euros (HVHL, 2017). The province of Frisia, the business community and the education generated this investment. After this four-year period, the innovation centre should be self-sufficient. This centre will enable companies from the food cluster in Northern part of the Netherlands to conduct research together with the education institutes. By means of this innovation centre knowledge gets developed concerning the theme food technology in Frisia, while students get in touch with companies and the developments in this field of study at the same time. The latter provides the food industry in North Netherland access to better-educated graduates from within their own region.

Knowledge diffusion in networks

The innovation centre for food technology could give a boost to the knowledge diffusion between the companies that the representatives indicate is minimal at the moment. Multiple companies indicate that they are internally focused, because the benefits of working together or visiting network events do not outweigh the costs. In addition, several respondents made clear that their company had enough possibilities to solve problems internally or, if that's not the case, via a contract research with knowledge institutions. Although the collaboration between farmers and knowledge institutions is considered to be successful, the system function knowledge diffusion got a low score of 2.8. This discontent was not literally put into words as a problem by most of the companies during the interviews, but the score clearly shows an unfulfilled need. Themes of interest are for example more cross-sectoral collaboration, smart sensoring and big data.

Guidance of the search

A possible cause for the lack of collaboration is the insufficiently shared vision between the companies. The respondents acknowledged that individual visions are clearly stated, but there is no umbrella institute that formulates a shared spot at the horizon, like the Watercampus and Innovatie Cluster Drachten do for the water technology and HTSM cluster. The Dairy Campus has the potential to function as this umbrella institute. The Dairy Campus is part of the Universiteit Wageningen and located in Leeuwarden. The goal of the Dairy Campus is to enhance sustainability within the dairy chain and make her future-proof, focused mainly on milk production (Dairy campus, 2017).

Market formation

The market for dairy products is fairly big and international. The respondents did not see any problems concerning this subject though, and the system function market formation again received the highest score. The market could however be better served; the system function entrepreneurial activities got a low score of 2.5. This is the lowest score of all the system functions for all of the clusters in question. The respondents described the cluster as traditional, with significant room for improvement in terms of entrepreneurship.

Entrepreneurial activities

The respondents mentioned multiple opportunities to create more entrepreneurship. Two examples will be discussed. Firstly there is a chance for Frisia, regarding the area of medical food. Dairy products contain a high concentration of nutrients, making it an excellent basis for consumer products that facilitate ageing in a healthy way. This is especially important for Frisia for the following reason. The population pyramid of Frisia in 2015 shows that an ageing population is an issue ageing, just as in the rest of the Netherlands (see appendix 4, figure 8). However, together with the net migration of inhabitants between 15-30 out of the province, this results in an above national average age of the Frisian citizen (Partoer, 2014). With a relatively large market of elderly, this forms an opportunity in combining knowledge and production of dairy to create medical food based on dairy.

Second, several experts noted the trend in the industry towards the use of big data. Using a mix of different sensors, farmers are able to gain insight in for example the health and fertility of their cows. It is also possible to adjust the nutrition of individual cows, based on its individual needs. In this light the foundation was laid for ‘Smart Dairy Farming’ in collaboration with Friesland Campina (Smart Dairy Farming, 2017). The aim is to connect stakeholders by means of this consortium in an effort to turn this innovation into practice. Initiatives like this also have a positive effect on the knowledge exchange between stakeholders.

To conclude, the most important reason for the presence of dairy processing companies in Frisia is the large production of milk by local dairy farms. Therefore a constant supply of milk production is crucial for the milk processing companies to stay located in Frisia. To this end, the subsystems of the RIS seem well aligned. However, the sector is still considered as traditional by most experts. Several initiatives take place to ensure the future oriented sustainable production of milk, but a common vision, a cluster organisation or a joint approach is not present. For this more future oriented process, the different subsystems of the RIS do not seem to align.

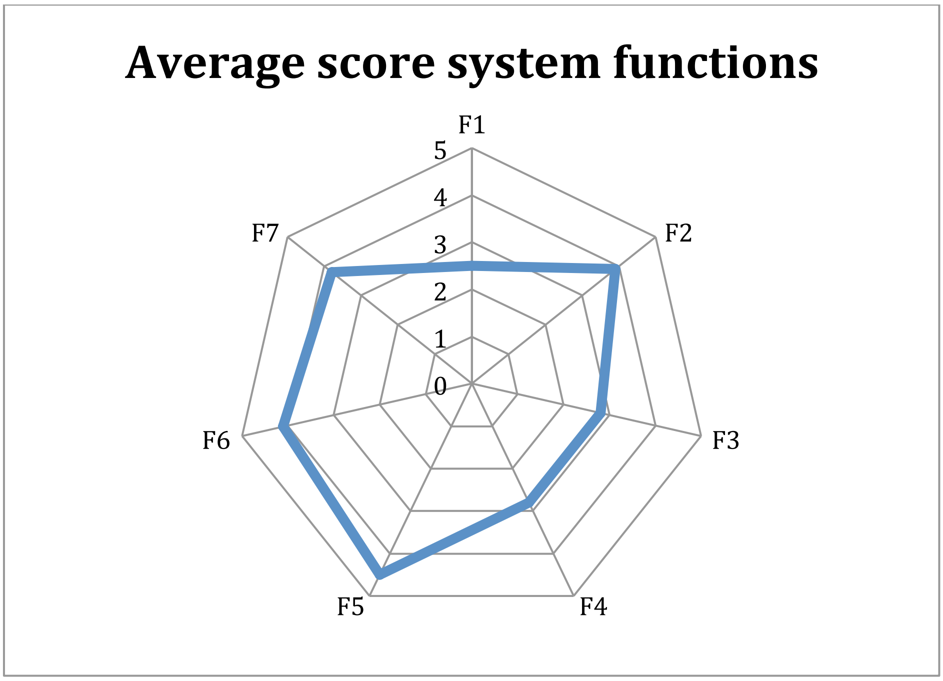

Figure 7: Average score system functions by five experts from the sector.

4.5 The Frisian RIS

Based on the different analysis, some conclusions can be given on the functioning of the Frisian RIS. To this end the values attributed to the system functions of the clusters are given in table 1. An average across all respondents is included. This average is used as representative for the RIS as a whole.

	F1 Entrepreneurial activities	F2 Knowledge development	F3 Knowledge exchange	F4 Guidance of the search	F5 Market formation	F6 Resource mobilisation	F7 Creation of legitimacy / counteract resistance to change
Average	3.5	3.8	3.2	3.3	4.6	3.7	4
HTSM	3.9	3.3	3.1	4.2	4.5	3.8	4.3
Water technology	3.9	4.5	3.6	2.8	4.8	3.1	3.8
Dairy / food	2.5	3.9	2.8	2.8	4.5	4.1	3.8

Table 1: average values per cluster

What is noticeable is that system function F5 (market formation) is valued very high by almost all the experts, with an average score of 4.6. This means that the experts in the three investigated clusters are positive about the market potential of their cluster.

Also system functions F7 (creation of legitimacy / counteract resistance to change), F2 (knowledge development) and F6 (resource mobilisation) are positively assessed on average, although there is more differentiation between the clusters. The most often mentioned improvements for these system functions were respectively to increase the visibility of the Frisian clusters both within and outside Frisia, increase specific knowledge production that fits with the needs of companies and lastly organise the availability of medium-sized loans for start-ups and SME's.

The system functions F1 (entrepreneurial activities), F4 (guidance of the search) and F3 (knowledge diffusion in networks) have received the lowest score by the experts. In all the clusters there was a need for more experimentation by entrepreneurs. According to some experts, students should be encouraged to broaden their knowledge as well as specialise in one area. Furthermore several experts (except from the HTSM cluster) stated that there was limited cooperation among firms within the region and also a lack of a shared vision by the cluster, although experts differed of opinion on this matter. This could be the reason for a relatively low score for F3 (knowledge diffusion in networks). Although, not all the entrepreneurs had a need for more knowledge exchange, because of limited use and high transaction costs.

The knowledge generation & diffusion subsystem is best developed for the water technology cluster due to the presence of Wetsus. The HTSM cluster and dairy/food clusters are more dependent on knowledge production from outside the region, but are both trying to increase local knowledge generation. The knowledge application & exploitation subsystem is best developed by the HTSM cluster due to the increased horizontal networking through the ICD. The water technology cluster consists mainly of small companies and can benefit from more horizontal networking with larger firms to gain access to work capital and foreign markets. Evidence from the HTSM and water technology clusters suggests that increasing the interaction between the knowledge generation and application subsystems is a good starting point to strengthen the subsystems.

The case study showed that there are large differences in the sectors making it impractical to determine the state of development of the RIS as a whole. The dairy/food cluster shows the characteristics of a peripheral, institutional RIS drawing upon a synthetic knowledge base as it is characterized as a traditional sector mainly applying existing knowledge. Due to the efforts of the ICD and increasing R&D expenditures, the HTSM cluster seems in the process to change from a peripheral, institutional RIS with a synthetic knowledge base to an entrepreneurial, metropolitan RIS with an analytical knowledge base. Last, since the arrival of Wetsus, the water technology cluster is best described as an entrepreneurial, metropolitan RIS with an analytical knowledge base.

5. Discussion

The discussion consists of three paragraphs. First, limitations of the research are discussed. Second, the theoretical implications of the research are discussed and implications for future research are provided. Last, the societal implications of the research are addressed.

5.1 Limitations

In this paragraph, the limitations of the research are addressed, based on which suggestions for future research are presented. Seven limitations to the research will be discussed. The first two limitations are linked to the application of the system function approach on a RIS. During the interviews, this framework proved very useful to structure the conversation and understand the processes and dynamics in the RIS. However, the choice to use this set of system functions, which was originally developed for the TIS, had two notable disadvantages.

First, all respondents limited their answers to the sector in which they are active, effectively resulting in a separate analysis for each cluster. The data from all clusters together was then used to describe the RIS, based on similarities in the fulfilment of the system functions. This approach limits the activities in the RIS to the activities of the three chosen clusters. On the other hand, it does make the research more manageable and incorporates the most important clusters for the Frisian economy (see appendix 6, figure 12).

Second, the experts indicated that the creation of legitimacy / counteract resistance to change (F7) was not deemed very relevant for the dynamics in their respective clusters. Though, the experts stipulated the positive publicity and the visibility of the clusters and their respective companies. Thus, the case studies did not point towards significant importance of the seventh system function. Future research can focus on further exploring the use of the system function approach on a RIS as a way to evaluate the dynamics within the RIS. Special attention should be given to the application of the seventh system function (creation of legitimacy / counteract resistance to change).

Third, the sample size of the research has a focus on innovative companies, which are often the larger and more successful companies. This is a limitation, because 99% of the Frisian companies are SME's, most of which are therefore excluded from this sample. However, the larger companies do have a more central place in the network of their respective cluster, making them ideal to quickly get an overview of the current state of affairs. Furthermore, since only one region is studied in this paper, the functioning of this specific region cannot be generalized. Notwithstanding, by describing the context of the research in detail, readers are able to apply the findings appropriately (Onwuegbuzie & Leech, 2007).

Fourth, the cluster concept is used to describe the collection of HTSM, water technology and dairy/food related companies in Frisia. On the other hand, compared to the definition of a cluster by Porter (1990), one can argue that these clusters are not geographically bounded to Frisia. Almost all experts under scribe this. They agreed that their company operated over the borders of the province and cooperated mostly with companies located in the three Northern provinces of the Netherlands. This scale level can also be seen in the members of the network organisations from all three sectors. Therefore, the term 'cluster' is mainly used to indicate a collection of companies from one sector within the geographical boundaries of a province. However, Frisia as a region is prudent to study instead of North Netherland as a whole, because each province has its own local government which may set and fund its own innovation related goals, leading to differences in the policy subsystem of the RIS (Cooke, 2001).

Fifth, limited attention was given to the fourth and fifth subsystem of the RIS concerning respectively policy and external influences from outside the RIS (see figure 1). The RIS is characterized as a highly open system with institutional influences from the NIS, international organizations and other RISs (Cooke, 2002). However, during the interviews the influence of these subsystems was not regarded problematic for the development of the Frisian RIS. For this reason, these subsystems got limited attention. It should be noted that this might change during periods of economic crisis, stringent regulations or other external factors that greatly influence the RIS.

Sixth, the aim of this research was to study peripheral regions without a well-developed RIS. The province Frisia was chosen for several reasons, among which its low innovative capacity (ING Economisch Bureau, 2015) and absence of a university. During the research however, it became clear that several interesting and innovative companies that are world market leader in their niche are located in Frisia, like Paques with anaerobic water purification systems and Kwant Controls with a global market in nautical equipment. Furthermore, companies in the water technology and HTSM clusters are actively shaping the RIS, by working together to overcome structural shortcomings like a limited supply of labourers with a higher education and attracting venture capital. In short, the chosen region proved less 'empty' than it seemed at first sight.

Last, the results of this research rely heavily on interview data. It would have been interesting to study the history of the region in more detail using local archive data. This is an implication for future research and would be interesting to compare with similar regions.

5.2 Theoretical implications and future research

This research shows evidence to suggest that there are successful (clusters of) SME companies located in areas that seem at first sight peripheral, which is in contrast to theory on RIS (Cooke, 2002). The aim of this research is to solve this puzzle and provide insight in the factors that make peripheral regions an interesting location to locate and grow as a company. The results from the analysis lead to two major theoretical implications.

First, this research provides insight in the early stages of regional development. In the analysis it became clear that firms located in Frisia did so for one or several of the following standard reasons. First, the majority of the companies from all clusters indicated that the relatively low costs of doing business compared to metropolitan regions contributed to the decision to locate in Frisia. Second, companies from the dairy / food and HTSM clusters valued the sufficiently educated and large supply of MBO schooled labourers. Since Wetsus was founded, water technology companies also point towards the steady supply of highly educated (HBO, University, PhD) labourers as an important factor to locate in Frisia. Third, mainly companies from the dairy / food cluster located in Frisia because of the long history of the province with dairy cattle farms. Locating close to the supply lowers transport costs and therefore production costs. Last, some of the larger companies received financial incentives by the province to locate in the province, adding to the previously named beneficial factors in the choice to locate in Frisia. This indicates that companies locating in peripheral regions do so for relatively standard reasons.

These results are to a certain extent in contrast with the idea that it is not possible to copy a successful RIS like Silicon Valley (Hospers et al., 2009). The case of the HTSM cluster in Frisia shows that the origin of the cluster can be traced back to settlement of production factories of Philips in Drachten. At the time Philips located in Frisia for relatively standard reasons, but it did form the nuclei from which an interesting IS started to emerge in the following decades. Thus, the arrival of a large company to a relative 'vacuum' marked the start of an endogenous process of regional development. The same pattern can be observed for the water technology cluster with Paques and the dairy cluster with Friesland Campina, although these companies were founded in Frisia. Therefore this research shows that the development of a RIS can either start with a local company or by attracting a large company, as long as it is able to tap into the place surplus of the region.

Second, this research provides insight in the reasons why firms stay located in a peripheral region in the early phases of the development of a RIS. The puzzle here is to determine to what extent the different building blocks of the RIS are geographically bounded. To this end, the set of system functions as defined by Hekkert et al. (2007) were chosen, because they have gone through extensive empirical validation and correspond well with the relevant processes in IS (Suurs & Hekkert, 2005; Negro et al., 2006). This research is, to our best knowledge, the first to apply the system function approach on a RIS. Furthermore, this research also used the system functions in a novel way. Instead of using the function approach to find bottlenecks or constraints in the development of a RIS (Bergek et al., 2008), the functions are used to identify the minimum requirements to develop a RIS. By choosing to identify the minimum requirements to develop a RIS, this research avoids the critique on the IS approach for its limited guidelines to policymakers (Bergek et al., 2008; Edquist, 2004).

The results show four system functions that were essential for the early development of the three clusters in Frisia, of which only one is geographically bounded. First, all clusters benefited from a strong market demand (F5). In all cases the market demand was not geographically bounded to Frisia, but came from the rest of the Netherlands and other countries (see appendix 6).

Access to relevant and state of the art knowledge production (F2) was deemed important by all of the clusters. However, there was no strong source of local knowledge production like an entrepreneurial university in the region, although they were available in neighbouring regions. Yet, the importance of the availability of locally produced knowledge increased across all sectors as the clusters started to develop, according to the experts. The increasing need of a higher educated workforce willing to work in Frisia can therefore be seen as an important reason to generate more knowledge locally.

The entrepreneurial activities (F1) seem to be most prominent in the firms that maximised the place surplus of the region in early stages of regional development. These are the same firms that in a later stage of regional development initiated cooperation with other local firms to overcome the shortcomings of the region. However only companies from the water technology cluster score high on entrepreneurial activities in early and later phases of regional development. The HTSM and dairy/food clusters started mainly with production facilities that slowly started to expand its R&D activities on site. Although much of the entrepreneurial experimentation of the dairy/food cluster has since been moved to Wageningen. The results therefore indicate that entrepreneurial experimentation is a prerequisite for early regional development, but it does not necessarily have to be initiated within the region. Furthermore, the low score for entrepreneurial experimentation from the dairy/food cluster shows it is also not a prerequisite for cluster development, as long as companies are still able to tap into the place surplus of the region.

The strong market demand was coupled with sufficient access to resources (F6), in terms of a large supply of MBO schooled labourers and access to government money to invest in regional development. This enabled all three of the clusters to capitalise on the strong market demand and is thus a strong geographically bounded system function needed to set the regional development into motion. An interesting finding from the interviews was that the sectors all seem to demand a larger supply of highly educated employees as they grow. This shift poses an increasing problem, since the data shows Frisia has a migration deficit of residents between fifteen and thirty years old who often do not return to the region after their study (appendix 4, figure 9). For the HTSM and water technology clusters this fact was one of the main reasons to start organizing in clusters and thus marking the start of a RIS.

Two system functions that were increasingly fulfilled by actors within the region were essential for the change of simply the clustering of companies towards actually building up a RIS. As previously discussed this change was marked by an increasing need of a higher educated workforce. This prompted the companies to organize themselves, share knowledge (F3) and increase their visibility towards other stakeholders like the local government, other companies and potential new employees. Essential in this step was the fact that the cooperation between companies was driven by self-organization. Only when problems arose on a system scale that companies were unable to solve by themselves did most companies proceed to meaningful cooperation with other local firms.

The cooperation between firms opened the way to collectively guide the search process (F4) towards overcoming shortcomings of the region. An interesting finding is that in both the water technology and the HTSM clusters, the initiative to strengthen the RIS came from the largest company in the cluster. Thus far this has most noticeably resulted in Wetsus for the water technology cluster and the ICD for the HTSM cluster. The dairy/food cluster is more traditional according to experts and most of the knowledge production, both public and private, takes place in Wageningen. The innovation centre for food technology for the dairy cluster and the dairy campus are joint attempts to promote cooperation among local companies and to produce more knowledge locally. However these initiatives yet have to prove their success.

The data from the interviews did not point towards resistance from the current social-technical regimes in one of the sectors. Therefore the remaining system function, creation of legitimacy (F7), cannot clearly be attributed as important in an early or later stage of regional development. However, several experts pointed out that a strong negative lobby towards their company or sector would have a hampering affect both on early and later development. It is therefore expected that the creation legitimacy is important both in an early and a later stage of development. Future research could further test this hypothesis.

The only geographically bounded system function essential for innovative industries to emerge turned out to be the availability of resources (F6). The other system function important at the start of the clusters (entrepreneurial activities (F1), knowledge production (F2) and market demand (F5)) can also be fulfilled by dynamics that are external of the region. The change of simply the clustering of companies towards a RIS is marked by self-organisation and is thus geographically bounded. Self-organisation gave rise to knowledge exchange between local companies (F3) and a collective guidance of the search process (F4) towards overcoming shortcomings of the region.

This implies that clusters can arise from government interventions, which is partly in contrast to the idea that RIS cannot be copied (Cooke, 1997). Thus, attracting a large company or knowledge institute can mark the start of an endogenous process of regional development. This upward trajectory shows a similarity with the evolution of an industry from early development to maturity as described by the industry life cycle literature (ILC) (Klepper, 1997). In early development a small number of firms explore technological opportunities and combine knowledge from different industries. As industries mature, they require access to local industry-specific knowledge, more advanced infrastructure and specialized institutions. The system function approach adopted in this research adds to the ILC by offering insight in the processes that need to be fulfilled to advance in the ILC.

The findings regarding the minimum requirements for the beginning of a RIS partly comply with the most important factors essential for start-up success in unlikely places identified by Mahroum (2016). These are: open and collaborative social and professional networks, low cost production and an entrepreneurial university. The low cost production was also important for success in Frisia. The open and collaborative social and professional networks were also present, due to the shared Frisian culture. The entrepreneurial university is not present in the province, although the water technology cluster seems to have found a solution to this problem with the creation of Wetsus. In accordance with Mahroum (2016) collaborations are made to compensate for factors that are not present in the region. However different RISs differ in their capacity to attract and absorb knowledge generated elsewhere (Trippl et al., 2017).

Last, differences in the development of the clusters suggest that the RIS cannot always be characterized as a whole, in contrast to earlier research (Cooke, 2002; Asheim et al., 2007; Tödtling & Trippl, 2005). The case study showed for instance that the HTSM and dairy/food sector mostly rely on a synthetic knowledge base in which localised learning within firms plays an important role. In contrast, the water technology sector draws upon an analytical knowledge base. This is characterized by the presence of Wetsus, which embeds the sector in the region by providing a knowledge infrastructure with access to relevant scientific knowledge and a local supply of high-skilled labour. Therefore we argue that differentiating factors in RIS do not support a ‘one size fits all’ approach to regional policy, following Asheim et al. (2011). Future research should further explore the way in which the demands of companies regarding their location change as they grow.

5.3 Societal implications

Several societal implications that can significantly benefit local governments and companies alike are proposed. In early stages of regional development, local governments can increase the chance to create new clusters by attracting either a large company or a knowledge institute. To this end, the place surplus of the region should be maximised. This can for instance be to ensure low production costs for companies as shown in this study.

As several companies locate in a region and the needs of companies become more complex, a focus on strengthening the structure and dynamics in the RIS becomes more important. Collaborations should be undertaken to compensate for factors that are not present in the region. It should be noted that this process is highly path dependent, based on the kind of companies that locate in the region in early stages of regional development (Garud & Karnoe, 2001).

Furthermore, this research provides evidence that local knowledge production is important for the development of a RIS, as many others found before (Cooke et al., 1997; Asheim & Coenen, 2005; Andersson & Karlsson, 2004). It is however not a prerequisite to succeed as knowledge can be acquired by collaboration with external knowledge producers, as also noted by Mahroum (2016). This is also shown in this research with the dairy / food cluster, which is strongly dependent on collaboration with Wageningen University for its knowledge production. However, as evidence from the water technology cluster suggests, a local knowledge production system that corresponds to the local knowledge application system does result in an increase in start-up companies in the region. The Wetsus model which relies on close cooperation with companies for its finance and research agenda proved very successful.

In line with the increasing importance of local knowledge production, access to highly skilled talent also becomes increasingly important. One of the problems with a highly developed RIS is that housing accommodation is becoming scarce and very expensive as can be observed in for instance Silicon Valley (Zhang, 2003). Therein lies a chance for peripheral RISs with an increasing need for highly skilled talent, as housing accommodations are still numerous. By organizing in clusters, companies can increase their visibility, and offer a perspective at high quality work in different companies in close proximity to each other. The proof of concept for this mechanism is provided by the ICD, which decreased the efforts of its members to attract talent.

6. Conclusion

In this paper, an answer is sought to the question why firms locate in unlikely places that do not at the first sight fulfil the requirements of a successful RIS and how they survive in these regions. To this end a case study is performed on the Dutch province Frisia, which is often described as traditional, with a low innovative performance and does therefore not fulfil the requirements of a successful RIS. Three clusters (HTSM, water technology & dairy/food) within Frisia have been analysed, as they are most important for the Frisian economy. First a desk research was executed to provide an overview of the structure of the Frisian RIS. Semi-structured interviews with representatives of companies that hold a central position in the cluster, based on for example size, revenue or innovativeness were conducted to map the seven different system functions.

In the analysis it became clear that firms locating in Frisia, did so for one or several of the following reasons: relatively low production costs compared to metropolitan regions, the presence of sufficiently large supply of MBO schooled labourers, the availability of resources (dairy farms) and last financial incentives by the local government. These results add to the factors essential for start-up success in unlikely places identified by Mahroum (2016). The results also show that regions that lack an entrepreneurial university can compensate for this fact by creating a local research institute in close collaboration with a university that has a clear focus on knowledge production important for firms in the region.

The system function approach was then used in a unique way, to find the minimum requirements that enabled local companies to grow and start clustering. The results showed that the entrepreneurial activities (F1), knowledge development (F2), market formation (F5) and the availability of resources (F6) were most important in an early stage of regional development, of which only the last was geographically bounded.

As time went by and the companies in the clusters grew in size, their demands also changed. This research shows that companies are willing to stay in Frisia to increasing extent because of the benefits they gain from organizing in clusters and creating supply chains in the region. Therefore knowledge exchange (F3) and guidance of the search process (F4) become increasingly important for the clusters to grow. Due to this process it becomes more likely for related companies to also locate in the region. Therefore a well-developed RIS becomes increasingly important for companies to stay located in a region, as the demands of companies start to change towards more knowledge intensive business.

This research has two major implications on theory. The system function approach, first applied to a RIS in this research, proved a valuable method to investigate if the structure of a RIS supports the development of its clusters. Second, this research shows that the reasons for firms to locate and stay in a region change as clusters start to emerge. At first, companies locating in peripheral regions do so for relatively standard reasons like low production costs, however as the companies grow and become more knowledge intensive, their demands also change and the functioning of the RIS becomes increasingly important.

For policy makers this indicates that in early stages of regional development, the chance to create new clusters can be increased by attracting a large company or a knowledge institute and identifying and maximising the place surplus of their region. As several companies locate in a region and the needs of companies become more complex, a focus on strengthening the structure and dynamics in the RIS becomes more important. To this end, attention should be given to the differences between the development of clusters and stimulate the cluster accordingly.

Future research should further verify the use of the system function approach on a RIS to identify the minimum requirements for development and as a way to evaluate the dynamics within the RIS. Furthermore, future research should provide further evidence to the way in which the demands of companies regarding their location change as they grow.

To conclude, locating in a developed metropolitan RIS is not a prerequisite to succeed as a company. Peripheral regions can also act as an attractive climate for entrepreneurs to develop their business.

7. References

Andersson, M., & Karlsson, C. (2006). Regional innovation systems in small and medium-sized regions. *The Emerging Digital Economy*, 55-81.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research policy*, *34*(8), 1173-1190.

Asheim, B., Coenen, L., & Vang, J. (2007). Face-to-face, buzz, and knowledge bases: sociospatial implications for learning, innovation, and innovation policy. *Environment and Planning C: Government and Policy*, *25*(5), 655-670.

Asheim, B. T., & Isaksen, A. (1997). Location, agglomeration and innovation: towards regional innovation systems in Norway. *European planning studies*, *5*(3), 299-330.

Asheim, B. T., Smith, H. L., & Oughton, C. (2011). Regional innovation systems: theory, empirics and policy. *Regional studies*, *45*(7), 875-891.

Autio, E. (1998). Evaluation of RTD in regional systems of innovation. *European Planning Studies*, 6, 131–140.

BBO Grontmij. (2012). *Watertechnologie Noord-Nederland: Groeiende sector met grote toegevoegde waarde.* Available online: http://wateralliance.nl/wp-content/uploads/2015/01/RAPPORT-WTNN-mv-BBO_Grontmij-onderzoek.pdf [Last visited: 06-05-2017]

Bergek, A. (2002). *Shaping and exploiting technological opportunities: the case of renewable energy technology in Sweden*. Göteborg, Sweden: Department of Industrial Dynamics, Chalmers University of Technology.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research policy*, *37*(3), 407-429.

Breschi, S. and Malerba, F. (1997). Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries. In: C. Edquist (Ed.), Systems of Innovation – Technologies, Institutions and Organizations. Pinter, London, pp. 130-156.

Bryman, A. (2012). *Social research methods.* Oxford university press.

Carlsson, B. and Stankiewicz, R. (1991). On the nature, function, and composition of Technological Systems. *Journal of Evolutionary Economics 1(2): 93-118.*

Carlsson, B., Stankiewicz, R. (1995). On the nature, function and composition of technological systems. In: Carlsson, B. (Ed.), Technological Systems and Economic Performance: The Case of Factory Automation. Kluwer, Dordrecht.

CBS. (2014). *Alle goederen dragen bij aan goederenexport.* Available online: https://www.cbs.nl/nl-nl/achtergrond/2014/09/ [Last visited: 13-09-2017].

CBS. (2017). Available online: https://www.cbs.nl [Last visited: 03-03-2017].

CBS. (2016). *Factsheet Friesland.* Available online: https://www.cbs.nl/nl-nl/nieuws/2016/14/export-buiten-eu-groot-in-friesland-en-noord-brabant [Last visited: 18-10-2017].

Cooke, P. (1992). Regional innovation systems: competitive regulation in the new Europe. *Geoforum*, *23*(3), 365-382.

Cooke, P. (2002). Regional innovation systems: general findings and some new evidence from biotechnology clusters. *The Journal of Technology Transfer*, *27*(1), 133-145.

Cooke, P., & Morgan, K. (1994). The creative milieu: a regional perspective on innovation. *The handbook of industrial innovation*, 25-32.

Cooke, P., Uranga, M. G., Etxebarria, G. (1997). Regional Innovation Systems: Institutional and Organisational Dimensions. *Research Policy* 26(4-5): 475-49.

Cooke, P., Uranga, M. G., & Etxebarria, G. (1998). Regional systems of innovation: an evolutionary perspective. *Environment and planning A*, *30*(9), 1563-1584.

Dairy Campus. (2017). *About Dairy Campus.* Available online: http://www.dairycampus.nl/en/Home/About-us.htm [Last visited: 11-10-2017].

Edquist, C. (2004). Systems of Innovation: Perspectives and Challenges. In: J. Fagerberg, D.C. Mowery and R.R. Nelson (Eds), *The Oxford Handbook of Innovation.* Oxford University Press, Oxford, pp. 181-208.

Feldman, M. P. (2001). The entrepreneurial event revisited: firm formation in a regional context. *Industrial and corporate change*, 10(4), 861-891.

Feldman, M. P., & Florida, R. (1994). The geographic sources of innovation: technological infrastructure and product innovation in the United States. *Annals of the association of American Geographers*, 84(2), 210-229.

Freeman, C. (1987). *Technology Policy and Economic Performance – Lessons from Japan.* Science Policy Research Unit, University of Sussex. Pinter, London and New York.

Freeman, C., & Soete, L. (1997). *The economics of industrial innovation*. Psychology Press.

Fries sociaal planbureau, 2017. *Samenstelling Friese bevolking verandert.* Available online: https://www.friessociaalplanbureau.nl/nieuws/samenstelling-friese-bevolking-verandert [Last visited 15-09-2017].

Fritsch, M., & Slavtchev, V. (2011). Determinants of the efficiency of regional innovation systems. *Regional Studies*, *45*(7), 905-918.

Fritsch, M., & Stephan A. (2005) Regionalization of innovation policy – introduction to the special issue, *Research Policy* 34(8), 1123–1127.

Garud, R., & Karnoe, P. (Eds.). (2001). *Path dependence and creation*. Psychology Press.

Hekkert, M.P., Negro, S., Heimeriks, G., Harmsen, R. (2011). *Technological Innovation System Analysis; manual for analysts.* Utrecht University.

Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change* 74, 413-432.

Hospers, G. J., Desrochers, P., & Sautet, F. (2009). The next Silicon Valley? On the relationship between geographical clustering and public policy. *International Entrepreneurship and Management Journal*, *5*(3), 285-299.

HVHL. (2017). Nieuw innovatiecentrum voedingsmiddelentechnologie in Leeuwarden. Available online: https://www.hvhl.nl/nieuws/items/2017/nieuw-innovatiecentrum-voedingsmiddelentechnologie-in-leeuwarden.html [Last visited: 09-10-2017].

ING Economisch Bureau. (2015). *ING Innovatie Index; Nederland klaar voor verandering?.*

ING Economisch Bureau. (2017). *Economie ZuidWest Friesland in 2017.* Available online: https://www.ing.nl/zakelijk/kennis-over-de-economie/uw-regio/vooruitzichten-regios/regios/zuidwest-friesland.html [Last visited: 18-08-2017].

Innovatiecluster Drachten. (2017). Available online: https://en.icdrachten.nl [Last visited: 25-09-2017].

Innovatiespotter. (2016). Available online: https://www.innovatiespotter.nl/downloads [Last visited: 04-05-2017].

Jacobsson, S., & Bergek, A. (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and corporate change*, *13*(5), 815-849.

Johnson, A. (2001). Functions in Innovation System Approaches. in Paper for DRUID's Nelson-Winter Conference.

Kaarten & Atlassen. (2017). Kaart Friesland 451. Available online: https://www.kaartenenatlassen.nl/wandkaarten/provinciekaarten/kaart-friesland-451 [Last visited: 08-09-2017].

Kamer van Koophandel. (2017). Available online: https://www.kvk.nl [Last visited 06-01-2017].

Klepper, S. (1997). Industry life cycles. *Industrial and corporate change*, *6*(1), 145-182.

Kline, S. J., & Rosenberg, N. (1986). An overview of innovation. *The positive sum strategy: Harnessing technology for economic growth*, *14*, 640.

Leeuwarder Courant. Several articals, publication data given in the tekst.
Link Magazine. (2016). Noord-Nederland, where great minds work: zelfscheppende industrie, slimme fabrieken. Available online: http://www.linkmagazine.nl/kenniskaart-noord-nederland/ [Last visited: 09-10-2017].

Lundvall, B.-Å. (1992). National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter, London.

Mahroum, S. (2016). *Black Swan Start-ups*. Palgrave Macmillan UK.

Meelen, T., & Farla, J. (2013). Towards an integrated framework for analysing sustainable innovation policy. *Technology Analysis & Strategic Management*, *25*(8), 957-970.

Metcalfe, J.S. (1995). Technology systems and technology policy in an evolutionary framework. Cambridge Journal of Economics *19: 25-46.*

Negro, S. O., Hekkert, M. P., & Smits, R. E. (2007). Explaining the failure of the Dutch innovation system for biomass digestion—a functional analysis. *Energy policy*, *35*(2), 925-938.

Nelson, R. (1993). *National Innovation Systems. A comparative analysis.* Oxford University Press, Oxford.

OECD, (2016). GDP per Capita. Available online: https://data.oecd.org/gdp/gross-domestic-product-gdp.htm. [Last visited: 12-12-2016].

Onwuegbuzie, A. J., & Leech, N. L. (2007). Validity and qualitative research: An oxymoron?. *Quality & Quantity*, *41*(2), 233-249.

Oost, H. (2003). *Circling around a question; defining your research problem.*

Partoer, 2014. *Bevolkingsontwikkelingen in Fryslân.* Available online: http://kknn.vanmeernaarbeter.nl/sites/vanmeernaarbeter.nl/files/Fluchtschrift_bevolkingsontwikkelingen_nov2014.pdf [Last visited: 08-09-2017].

Patel, P., & Pavitt, K. (1994). National innovation systems: why they are important, and how they might be measured and compared. *Economics of innovation and new technology*, *3*(1), 77-95.

Porter, M. E. (1990). The competitive advantage of nations. *Harvard business review*, *68*(2), 73-93.

Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard business review,* 98(6), 77-90.

Provincie Friesland. (2017). Programma economie, toerisme en recreatie. Available online: http://www.fryslan.frl/4117/programma-6-economie,-toerisme-en-recreatie/ [Last visited: 13-03-2017].

RVO. (2017). High Tech Materialen Topsector HTSM. Available online: https://www.rvo.nl/subsidies-regelingen/high-tech-materialen-topsector-htsm [last visited: 10-09-2017].

Saxenian, A. (1990). Regional networks and the resurgence of Silicon Valley. *California management review*, *33*(1), 89-112.

Scopus. (2016). Available online: https://www.scopus.com/home.uri [Last visited 12-12-2017].

Smallingerland. (2017). *Drachten en Dorpen.* Available online: https://www.smallingerland.nl [last visited: 13-09-2017].

Smart Dairy Farming. (2017). Available online: https://smartdairyfarming.nl. [Last visited: 28-09-2017]

Suurs, R. & Hekkert, M. P. (2005). *Naar een methode voor het evalueren van transitietrajecten, functies van Innovatiesystemen toegepast op biobrandstoffen in Nederland.* Utrecht University, department of Innovation Studies: Utrecht.

Trippl, M., Grillitsch, M., & Isaksen, A. (2017). Exogenous sources of regional industrial change: Attraction and absorption of non-local knowledge for new path development. *Progress in Human Geography*.

Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. *Research policy*, *34*(8), 1203-1219.

Werker, C. (2006). *An Assessment of the Regional Innovation Policy by the European Union based on Bibliometrical Analysis.* Papers on Economics and Evolution Number 2006-11. Max Planck Institute of Economics, Evolutionary Economics Group, Jena.

Wetsus. (2017). *Combining scientific excellence with commercial relevance.*

Wikipedia. (2017). *Friesland.* Available online: http://wikipedia.nl/friesland [Last visited: 13-04-2017].

Wsstp. (2017). Water and Friesland. Available online: http://wsstp.eu/communities/regional-representation/friesland-region/ [Last visited: 15-04-2017].

Zhang, J. (2003). *High-tech start-ups and industry dynamics in Silicon Valley*. Public Policy Instit. of CA.

8. Appendices

Appendix 1 – Interview questions

General

- What is your expertise?
- Do you think the scale of Frisia as province is important for formulating innovation policy?
- What are the most important markets and grow markets the Frisian economy?

Functions

1. Is the amount of Frisian entrepreneurial experimentation and focus on sales production sufficient to sustain or enlarge the Frisian economy on the long term (+- 10 years)?
    - Do you see any differences per sector?

2. Is the type, amount and the quality of Frisian knowledge production sufficient to sustain existing and facilitate new companies in Frisia?
    - Do you see any differences per sector?

3. Is the amount of knowledge exchange between the different actors (knowledge institutes, companies, policy makers) sufficient to stimulate the economic development of the province Frisia?
    - Do you see any differences per sector?

4. Is there a clear vision how the Frisian industries and markets should develop; does the vision align between the different actors and policy goals?
    - Do you see any differences per sector?

5. Is the current and expected market size sufficient and is it created by a diverse amount of companies to sustain or enlarge the economy of the province Frisia?
    - Do you see any differences per sector?

6. Are there sufficient human, financial and physical resources to support economic development of the province Frisia?
    - Do you see any differences per sector?

7. Is there any resistance against policy or company goals and what is done to prevent or manage this resistance?
    - Do you see any differences per sector?

Additionally:

- What are the most important barriers for further economic development of the province Frisia?
- What are possible solutions to the identified barriers and who is responsible to act upon them?

Appendix 2 – List of companies that participated in the research

Cluster	Company	Selection basis
HTSM	Philips Consumer Lifestyle BV	1. Largest company Innovation Cluster Drachten
	Whisper Power	1. Subsidy IPC consortium granted 2. High score on Innovation spotter (Innovatiespotter, 2016)
	Kwant-Controls	1. World market leader in their field 2. Member of Innovation Cluster Drachten
	Antea Group	1. Very large international operating company with their headquarters in Frisia 2. Key position
	Berenschot	1. Consulting company managing the development of Innovation Cluster Drachten 2. Key position
	Stertil	1. Top patent applicant 2. Not member of Innovation Cluster Drachten
Water-technology	Paques	1. Largest company of the cluster 2. Top patent applicant 3. Several large subsidies have been granted
	Wetsus	1. Largest knowledge institute in its field in Frisia 2. Most patent applications cluster 3. Several large subsidies have been granted
	Wateralliance	1. Network organisation
	Aqana	1. Relatively new small company 2. Patent applications
	Redstack B.V.	1. Top patent applicant 2. High score on Innovation spotter (Innovatiespotter, 2016)
Dairy	Friesland Campina	1. Largest company with most settlements in Frisia 2. Several large subsidies have been granted
	Agro-Vital B.V.	1. Subsidy application for R&D collaboration project 2. Supplier
	Huhtamaki Nederland	1. Large company 2. Top patent applicant
	Dairy Campus	1. Network organisation
	CSK Food Enrichment B.V.	1. Large company 2. Top patent applicant

Appendix 3 – Largest companies of the clusters

HTSM cluster

The innovationcluster Drachten is a collaboration between 15 companies, with Philips as the largest company. Together these companies are responsible for approximately 3500 jobs in the region, ranging from academics to production workers. The collaboration between the R&D departments focuses on the most important themes within the High Tech industry; 3D metal printing, remote sensoring en big data, robotics, visual intelligence en all electric propulsion (Innovatiecluster Drachten, 2017). The cluster is responsible for over 50 product launches worldwide per year. Table 8 provides an overview of the affiliated companies of Innovationcluster Drachten.

Name company
Philips Drachten
BD Kiestra
Neopost Technologies
Photonis (Groningen, Roden)
Norma Group
Irmato
Kwant Controls
Resato international
Delta Instruments
Whisper power
YP Your Partner
ZiuZ visual intelligence
Science & technology bv
Variass
VDH products BV

Table 8: Overview of affiliated companies of Innovation cluster Drachten (Innovatiecluster Drachten, 2017).

Table 9 gives an overview of the companies from the HTSM cluster with over 100 employees. Only a small part of the largest companies in the HTSM sector are a member of Innovation cluster Drachten.

Name company	Place	Business code	Size class
Philips Consumer Lifestyle B.V.	Drachten	Manufacture of electrical household appliances	1000+
Accell Nederland	Heerenveen	Manufacture of bicycles and vehicles for disabled people	500-799
Antea Nederland B.V.	Heerenveen	Engineering and technological design	200-499

BD KIESTRA	Drachten	Manufacture of communication equipment	200-499
De Vries Scheepsbouw Makkum	Makkum	Construction of recreational boats	200-499
Neopost Technologies B.V.	Drachten	Manufacture of office machinery and equipment	200-499
Stertil B.V.	Kootstertille	Manufacture of hoisting, lifting and transport equipment	200-499
VDL Bus Heerenveen B.V.	Heerenveen	Carriage body work	200-499
Ardagh Metal Packaging Netherlands B.V.	Leeuwarden	Manufacture of metal packaging materials	100-199
Beenen B.V.	Heerenveen	Manufacture of switchgear	100-199
Carrosseriefabriek Heiwo B.V.	Wolvega	Carriage body work	100-199
De Jong Gorredijk B.V.	Gorredijk	Manufacture of metal tanks and reservoirs	100-199
FIB Process Equipment	Leeuwarden	Manufacture of metal tanks and reservoirs	100-199
Hertel B.V.	Drachten	Manufacture of machines (other)	100-199
Landustrie Sneek B.V.	Sneek	Manufacture of machines and devices (other)	100-199
Meijer Metal B.V.	St.-Jacobiparochie	Manufacture of machines and devices (other)	100-199
Miedema	Winsum	Manufacture of agriculture machinery	100-199
Neways Leeuwarden B.V.	Leeuwarden	Manufacture of electronic components	100-199
Norma IMS ECP B.V.	Drachten	Manufacture of tools	100-199
Oreel Hallum B.V.	Hallum	Manufacture of metal construction work	100-199
Rotocoat Wolvega B.V.	Wolvega	Surface treatment and metal coatings	100-199
Royal De Boer Stalinrichtingen B.V.	Leeuwarden	Manufacture of agriculture machinery	100-199
SMST Designers & Constructors B.V.	Drachten	Manufacture of hoisting, lifting and transport equipment	100-199
Tetra Pak Cheese and Powder Systems B.V.	Heerenveen	Manufacture of agriculture machinery	100-199

Table 9: Overview of 24 HTSM companies located in Frisia with over 100 employees (KvK, 2017).

Dairy / food cluster

The dairy / food cluster consists for the greater part of farms in the Province Frisia. However, this study focuses on the larger companies with a larger innovative capacity. The larger companies are roughly categorized by: the food processing industry, machine suppliers for agriculture and distributors (see table 10).

Name company	Place	**Business code**	Size class
FrieslandCampina Nederland B.V.	Leeuwarden	Manufacture of dairy products (no ice)	800-999
O. Smeding en Zoon B.V.	St.-Annaparochie	Wholesale of fruit and vegetables	200-499
Coöperatie AB Vakwerk Groep UA	Sneek	Agri- & horticulture services	200-499
Van Nelle Tabak Nederland B.V.	Joure	Manufacture of tobacco products	200-499
Hochwald Foods Nederland B.V.	Bolsward	Manufacture of dairy products (no ice)	200-499
BRF B.V.	Oosterwolde	Manufacture of ready meals	200-499
Hellema Hallum B.V.	Hallum	Manufacture of biscuit, cookies, etc.	200-499
FrieslandCampina Nederland B.V.	Wolvega	Manufacture of dairy products (no ice)	200-499
Frisia Food B.V.	Haulerwijk	Poultry slaughterhouse	200-499
Jacobs Douwe Egberts NL B.V.	Joure	Coffee and tea processing	200-499
CSK Food Enrichment C.V.	Leeuwarden	Wholesale (other)	100-199
Friesche Banketcentrale Bergsma Makkum	Franeker	Wholesale tobacco products	100-199
ActiFood B.V.	Oosterwolde	Wholesale (other)	100-199
Body & Fit Sportsnutrition B.V.	Heerenveen	Wholesale (other)	100-199
Sligro	Drachten-Azeven	Wholesale of food and stimulants	100-199
Makro Zelfbedieningsgroothandel	Leeuwarden	Wholesale of food and stimulants	100-199
Hartman Kwekerijen B.V.	Sexbierum	Cultivation fruit and vegetables	100-199
Miedema	Winsum	Manufacturing agriculture machinery	100-199
Royal De Boer Stalinrichtingen B.V.	Leeuwarden	Manufacturing agriculture machinery	100-199
Tetra Pak Cheese and Powder Systems B.V.	Heerenveen	Manufacturing agriculture machinery	100-199
Helwa Wafelbakkerij B.V.	Hallum	Manufacture of biscuit, cookies, etc.	100-199
Marine Harvest Sterk B.V.	Lemmer	Fishprocessing	100-199
Sonac Burgum B.V.	Sumar	Slaughterhouse (no poultry)	100-199
FanoFineFood	Oosterwolde	Manufacture of ready	100-199

		meals	
Continental Candy Industries B.V.	Drachten	Manufacture of chocolate and sugar confectionery	100-199
Holiday Ice B.V.	Sint Nicolaasga	Manufacture of ice cream	100-199
FrieslandCampina Nederland B.V.	Workum	Manufacture of dairy products (no ice)	100-199
FrieslandCampina Nederland B.V.	Gerkesklooster	Manufacture of dairy products (no ice)	100-199
Smeshing B.V.	St.-Annaparochie	Processing of fruits and vegetables	100-199
Koninklijke Peijnenburg	Sintjohannesga	Manufacture of biscuit, cookies, etc.	100-199
United Coffee	Bolsward	Processing of coffee and tea	100-199
Cloetta Holland B.V.	Sneek	Manufacture of chocolate and sugar confectionery	100-199
Lamb Weston Meijer Vestiging Oosterbierum	Klooster Lidlum	Manufacture of potato products	100-199
Romi Smilfood	Heerenveen	Manufacture of dairy products (no ice)	100-199
A-ware Milk Processing B.V.	Heerenveen	Manufacture of dairy products (no ice)	100-199

Table 10: Overview of 36 dairy / food companies located in Frisia with over 100 employees (KvK, 2017).

It is noticeable that FrieslandCampina is the dominant player in this sector, with four large companies spread throughout Frisia. Furthermore, the main focus of the food processing industry is on dairy related products.

Water technology cluster

The water technology cluster mostly consists of relatively small companies. There are no distinct categories in the chamber of commerce database to indicate companies active in water technology, making it difficult to produce a conclusive list of companies active in this sector. Table 11 provides an overview of companies active in the water technology sector in Frisia with more than 10 employees.

Name company	Place	Business code	Size class
Paques B.V.	Balk	Manufacture of other machinery and equipment	100-199
Landustrie Sneek B.V.	Sneek	Manufacture of other machinery and equipment	100-199
Hubert Stavoren B.V.	Stavoren	Manufacture of other machinery and equipment	50-99
Wetsus	Leeuwarden	R&D	50-99
Mefiag B.V.	Heerenveen	Manufacture of other	20-49

		machinery and equipment	
Dutch Water Technologies B.V.	Sneek	Architects, engineers and technical design and advice	10-19
Econvert Water & Energy Services B.V.	Heerenveen	Architects, engineers and technical design and advice	10-19
Knip International B.V.	Heerenveen	Manufacture of other machinery and equipment	10-19
Sticht. Centre of Expertise Water Technologie	Leeuwarden	R&D	10-19
Wateralliance	Leeuwarden	R&D	10-19

Table11: Overview of 10 water technology companies located in Frisia with over 10 employees (KvK, 2017).

Appendix 4 – Demographics Frisia

In the population pyramid in figure 8 two things stand out. First, there are relatively few residents between 20-30 years old. Furthermore the baby boom generation is clearly visible with an average age of 65 years.

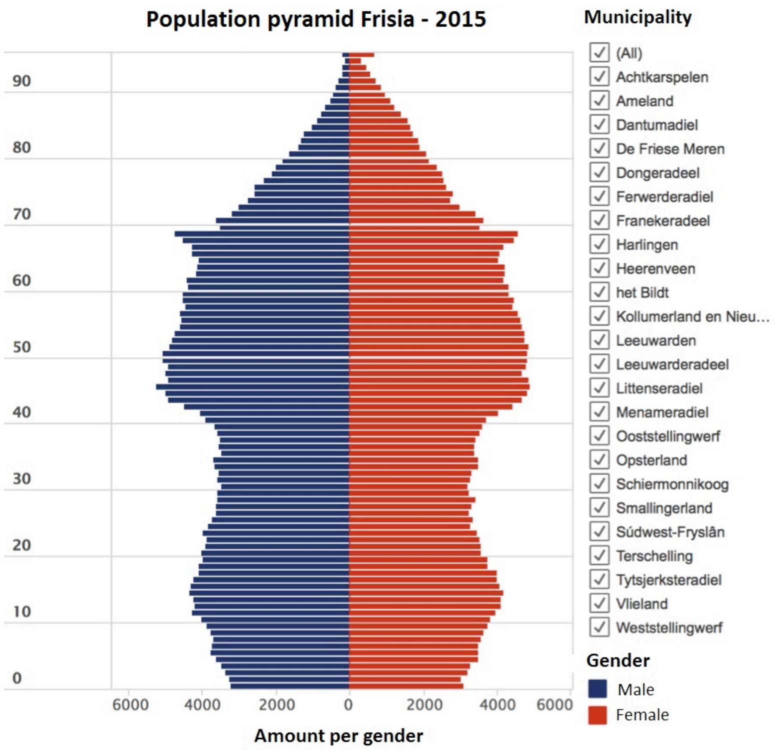

Figure 8: Population Pyramid Province Frisia (Fries Sociaal Planbureau, 2017).

Figure 9 shows an overview of the difference between residents who migrate to and out of Frisia between the years 2000-2016, divided by age groups. It can be concluded that Frisia has had a surplus of residents moving out of the province during this period, with the exception of the year 2016.

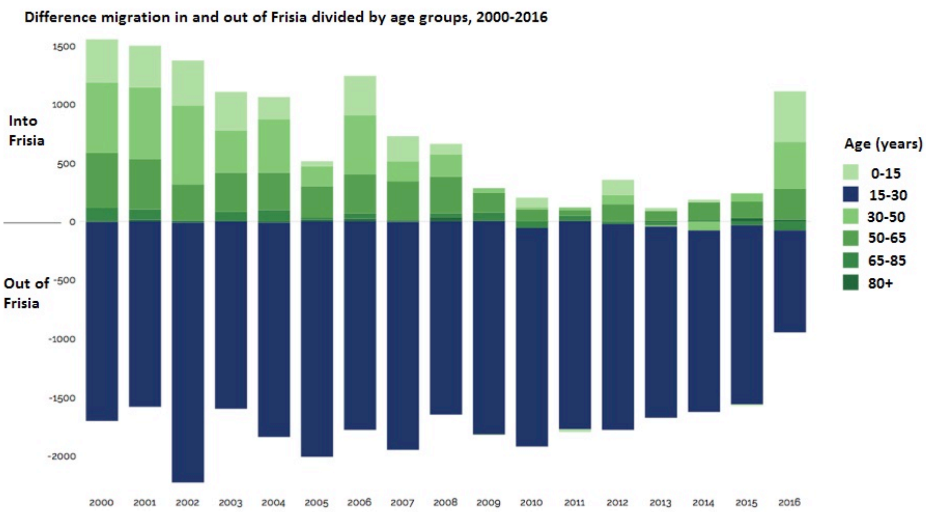

Figure 9: difference migration in and out of Frisia divided by age groups, 2000-2016 (Fries Sociaal Planbureau, 2017).

Appendix 5 – Population characteristics Frisia

Table 1 shows the education level in a percentage of the Frisian labour force compared to the Dutch average (2017). The low and middle level educated part of the Frisian labour force scores above the Dutch average between 2013-2015. The labour force with a high education level score below the Dutch average and seems to slightly decrease between 2013-2015, in contrast to the average trend in the Netherlands.

Education level	Scale level	2013	2014	2015
High	Netherlands	32,8	33,6	34,4
	Frisia	26,3	25,8	25,9
Middle level	Netherlands	42,4	42,7	42,2
	Frisia	47,5	48,0	48,5
Low	Netherlands	23,0	22,7	22,5
	Frisia	24,5	24,9	24,7

Table 12: Education level in percentage of labour force between 2013-2015 (CBS, 2017).

Table 2 shows a decrease in unemployment rate as a percentage of the labour force between 2013-2015 (CBS, 2017). This trend is present in all parts of Frisia, in accordance to the average trend in the Netherlands.

Scale level	2013	2014	2015
Netherlands	7,3	7,4	6,9
North-Frisia	8,3	8,2	7,8
Southwest-Frisia	7,1	7,3	6,3
Southeast-Frisia	7,7	8,1	7,2

Table 13: Unemployment rate in percentage of labour force between 2013-2015 (CBS, 2017).

In table 3 an overview of the total amount of bankruptcies of Frisian companies between 2013-2015 is given (CBS, 2017). In this period the amount of bankruptcies consistently decreased, corresponding the decrease in unemployment in the same time period as indicated in table 2.

Scale level	2013	2014	2015
North-Frisia	160	110	68
Southwest-Frisia	46	47	19
Southeast-Frisia	96	84	63

Table 14: Total bankruptcies between 2013-2015 (CBS, 2017).

Appendix 6 – Import and Export Frisia

Figure 10 shows the international export of Frisia per country in 2014 (CBS, 2016). The most prominent trading partners are the neighbouring countries Belgium and Germany. An interesting data point in this figure is the large amount of export to 'other countries'.

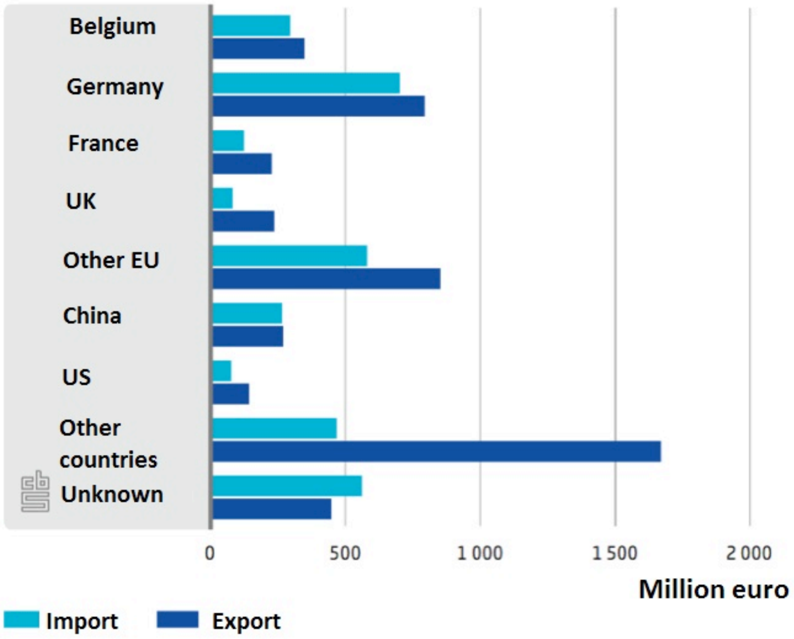

Figure 10: International import and export of Frisia per country in 2014 (CBS, 2016).

In figure 11 a comparison of Frisian export to non-EU countries with the other Dutch provinces is given (CBS, 2016). This figure shows that Frisia has the highest percentage of export to non-EU countries of all Dutch provinces, with approximately 45% of its total export in 2014.

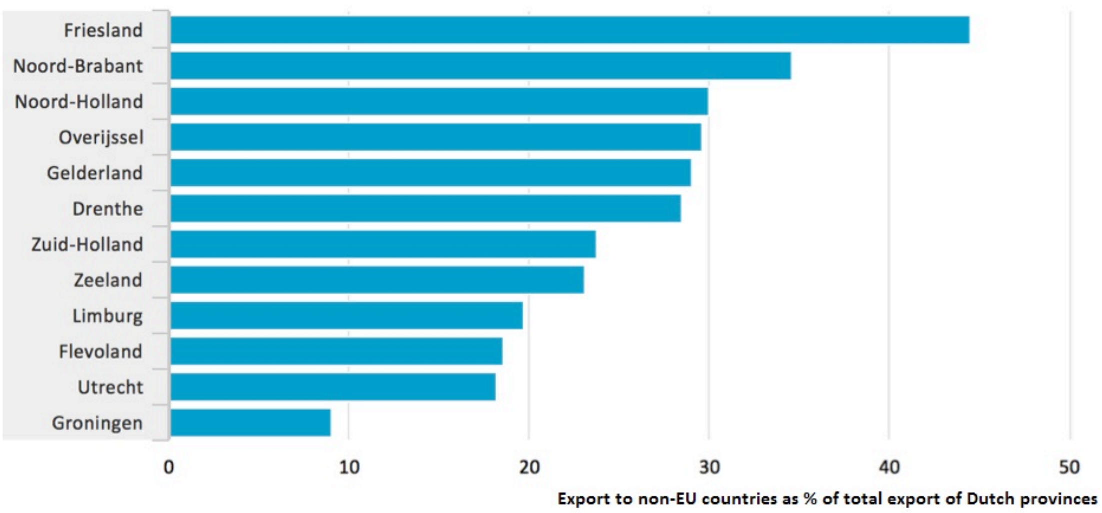

Figure 11: Export of Dutch provinces to non-EU countries as percentage of the total export in 2014 (CBS, 2016).

Figure 12 shows a breakdown of Frisian export for different kinds of goods (CBS, 2016). About half of the export consists of food and beverages and machines and transport equipment. Furthermore, a relatively large part of the composition of the Frisian export is unknown to the CBS.

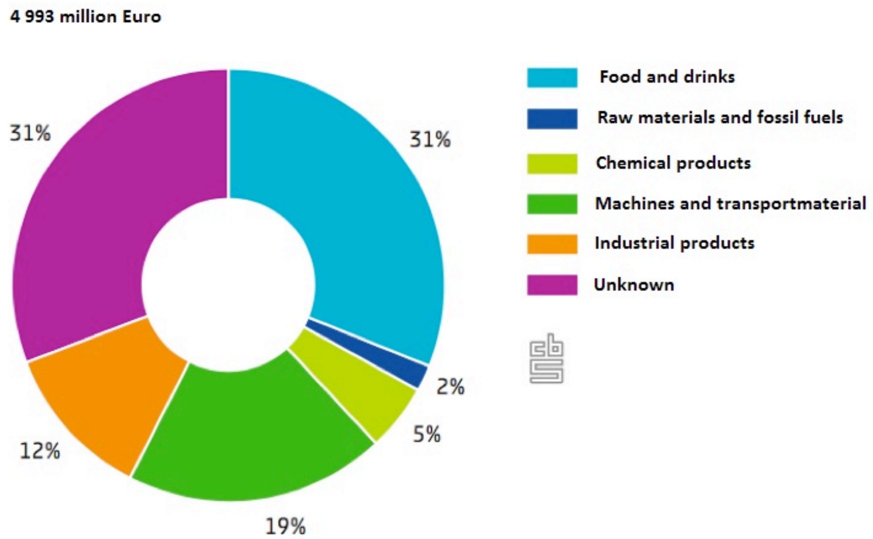

Figure 12: Breakdown of Frisian exports in 2014 into categories (CBS, 2016).

Appendix 7 – Subsidies

There are many different subsidies that SME's can apply for. The largest and best-known subsidy programs will be discussed. On the European level there are two major programs: the EFRO (European fund for regional development) and the Horizon 2020 (successor of the European Seventh frame work program to stimulate the international collaboration between companies and scientific institutions, within and outside Europe). On the national level there are also two major programs: the MIT (Mkb-innovation stimulation Region and Topsectors) and the WBSO (to reduce R&D costs for companies). Lastly, on the regional and provincial level two programs are available as well: the VIA (accelerator innovation ambitions) and the Doefonds Fryslân Fernijt (Program from the province itself). As the scale of the innovative project increases, the amount of subsidy that can be applied for also increases up to millions of Euros.

The overview below provides insight in the total amount of subsidies granted for innovation projects between 2010-2016 in Frisia. The data was obtained by the Netherlands Entrepreneurship Agency (RVO, 2017). The innovation projects were attributed to the province Frisia by use of a self made script that transformed geo-coordinates from the original database into zip codes. The zip codes were then matched to Frisia. Subsequently, every subsidies program has been given an overview regarding the amount and total sum of the subsidies in the period 2010-2016 (see table 15).

Subsidy programs	Amount of subsidies 2010-2016	Total sum of subsidies 2010-2016
Nederland; Topsector Water; Technologische Topinstituten	3	€ 23.492.524
Europa; Zevende Kaderprogramma	9	€ 16.735.328
Nederland; Seed Capital	2	€ 8.000.000
Innovatieprogramma Food & Nutrition Delta; Nederland; Topsector Agri & food	4	€ 1.550.904
Industriële Warmtebenutting; Nederland; Topsector Energie	2	€ 1.215.385
Nederland; Topsector Water; Subsidieregeling Innovatieve Zeescheepsbouw	1	€ 1.134.628
Innovatie Prestatie Contracten; Nederland	26	€ 963.964
Innovatie Prestatie Contracten; Nederland; Topsector Water	26	€ 895.000
Nederland; TKI Gas; Topsector Energie	1	€ 845.806
Nederland; TKI Wind op Zee; Topsector Energie; Wind op zee	1	€ 738.414
Nederland; Topsector Water; Innovatieprogramma Watertechnologie	2	€ 640.983
Effectieve en Efficiënte Vergistingketen; Nederland; Topsector Energie	1	€ 503.290
Eurostars; Europa; Topsector Life Sciences & Health	1	€ 500.000
Nederland; Regeling Internationaal innoveren; Topsector Agri & food	1	€ 399.991
Innovatiekrediet; Nederland	1	€ 340.200
Mkb-innovatiestimulering Topsectoren; Nederland; Topsector	2	€ 333.040

HTSM		
Innovatie Prestatie Contracten; Nederland; Topsector HTSM	5	€ 122.780
Mkb-innovatiestimulering Topsectoren; Nederland; Topsector Tuinbouw en uitgangsmaterialen	2	€ 118.258
Nederland; Regeling Internationaal innoveren	1	€ 117.825
Mkb-innovatiestimulering Topsectoren; Nederland; Topsector Logistiek	2	€ 101.400
Innovatie Prestatie Contracten; Nederland; Topsector Life Sciences & Health	3	€ 100.000
Innovatie Prestatie Contracten	4	€ 86.166
Innovatie Prestatie Contracten; Nederland; Topsector Creatieve industrie	3	€ 65.356
Mkb-innovatiestimulering Topsectoren; Nederland; Topsector Energie	1	€ 50.000
Innovatie Prestatie Contracten; Nederland; Topsector Tuinbouw en uitgangsmaterialen	1	€ 30.000
Nederland; TKI Agri&Food; Topsector Agri & food	1	€ 29.550
Innovatie Prestatie Contracten; Nederland; Topsector Energie	1	€ 25.000
Innovatie Prestatie Contracten; Nederland; Topsector Logistiek	1	€ 25.000
Innovatie Prestatie Contracten; Nederland; Topsector Agri & food	1	€ 19.624
Total	**118**	**€ 59.180.416**

Table 15: Overview granted subsidies per subsidy program in the period 2010-2016 (RVO, 2017).

Most of the larger granted subsidies came from the national subsidy program MIT. It is noticeable that the largest subsidies were attributed to the topsector water. Next to that, a significant subsidy came from the predecessor of the European H2020 subsidy program. However, based on the information from the database this cannot be attributed to a specific project or company.
To get more insight into the kind of innovation projects that receive subsidies, the innovation projects were arranged manually according to 120 different technology classes. This method is used also by the RVO, although that particular dataset is not publically available. For this reason it was made manually (see table 16).

TIS category	Amount of subsidies 2010-2016	Total sum of subsidies 2010-2016
Fundamental research	3	€ 23.492.524
Not a TIS	20	€ 8.563.736
Purification technology	3	€ 6.562.091
Blue energy (osmosis e.d.)	3	€ 2.404.745
Wind on see	1	€ 1.920.470
Ship innovations (smarter and cleaner)	22	€ 1.904.628
Breeding	1	€ 1.879.328

Product technology for food products	3	€ 1.780.876
Fermentation of biomass	4	€ 1.641.846
Valorisation organic residues	3	€ 1.593.439
ICT applications	4	€ 1.165.811
Automotive	3	€ 1.165.780
Process intensification in the industry	4	€ 1.072.000
Residual heat	1	€ 839.271
Aeronautics	1	€ 738.414
Not enough information	9	€ 562.825
Medicine R&D	1	€ 500.000
Architecture and design	1	€ 340.200
Homecare, ICT, e-health & self-management	7	€ 214.000
Enabling' technologies & research equipment	1	€ 196.000
Precision farming	2	€ 118.258
Innovative building materials	3	€ 105.000
Delta technology	3	€ 75.000
Biobased materials	2	€ 55.000
Packaging technology	2	€ 55.000
Not divided in existing LSH categories	1	€ 50.000
Offshore maritime innovations	2	€ 50.000
Energy efficient construction (passive, neutral, etc.)	3	€ 30.000
Innovative greenhouses (semi-closed greenhouses, CO2 capture, etc.)	1	€ 30.000
Biomass products / biomaterials	2	€ 29.550
Geothermal	1	€ 25.000
Innovation for animal health (including animal feed)	1	€ 19.624
Total	**118**	**€ 59.180.416**

Table 16: Overview of granted subsidies per technology category in the period 2010-2016 (RVO, 2017).

This table shows that the greater part of the subsidies was granted to the water cluster. This can be explained partly by the presence of Wetsus, which received a lot of money for research. Although it also seems that the water technology cluster is better in claiming these subsidies.

The WBSO makes it more attractive for companies to invest in R&D, by sharing in the salaries and other costs like the purchase of equipment. The amount of acknowledged

WBSO is an accurate size for the R&D concentration in a region. The Frisian province provided the WBSO data of 2014. To protect the privacy of the participating companies, it is not made public which companies received what amount of WBSO. Instead, the data was made available on COROP level.

Looking at the total of expenses of R&D (sum loan costs + remaining costs) per head of population in 2014, Frisia scores in the middle, as seen in table 17.

Province	R&D per resident (in Euro), 2014	ranking
Brabant	642,1989529	1
Gelderland	332,1619327	2
Limburg	295,8354712	3
Noord-Holland	280,3676003	4
Overijssel	270,3661867	5
Zuid Holland	253,7373972	6
Utrecht	250,2615894	7
Friesland	169,9164395	8
Flevoland	148,5621082	9
Groningen	145,1002658	10
Zeeland	132,1297022	11
Drenthe	123,5606929	12

Table 17: Overview of acknowledged R&D costs per inhabitant per province in 2014 (RVO, 2017).

However, when looking at the COROP areas and the amount of companies that invest in R&D (see table 18) the region South-east Frisia holds place 6, of the 40 places in total. This means that in the HTSM cluster, an industry with a large focus on R&D, contains a relatively large part of the total amount of companies in the region.

COROP areas	Amount of WBSO companies (2014)	Relative amount of WBSO companies (2014)	Ranking
Nederland	20331	1,49%	X
Twente	1305	2,93%	1
Delft en Westland	557	2,85%	2
Zuidoost Noord-Brabant	1585	2,54%	3
Achterhoek	656	2,08%	4
Zuidwest Overijssel	214	2,05%	5
Zuidoost Friesland	274	1,91%	6
Zuidwest Friesland	133	1,05%	33
Noord Friesland	213	0,89%	38

Table 18: Overview of the percentage of companies investing in R&D per COROP area in 2014 (RVO, 2017).

Appendix 8 – Patent data

Patent data is used as an indicator for the R&D activity and the knowledge basis of the clusters in the province Frisia. Table 19 provides an overview of the amount of granted patents companies located in Frisia between 2005-2014. Most patents were granted to a relatively small amount of companies. Furthermore, some companies like FrieslandCampina and Philips are missing in these statistics, because their headquarters is not placed in Frisia. Patents are often filed on the name of the headquarters of a company.

Company name	Patent granted 2005-2014
CSK Food Enrichment B.V.	19
Stichting Wetsus Centre of Excellence for Sustainable Water Technology	18
Lankhorst Engineered Products B.V.	14
Paques B.V.	13
Huhtamaki Nederland B.V.	11
Dutch Water Technologies B.V.	10
Gebr. Meijer St. Jabik B.V.	8
STERTIL B.V.	8
Redstack B.V.	8
Batavus B.V.	7
BD Kiestra B.V.	5
Biddle B.V.	5

Table 19: Overview of Frisian companies who were granted more than 5 patents in the period 2005-2014.

When comparing the granted of the past 10 years with the granted patents of the past 5 years gives a comparable list (see table 20).

Company name	Patents granted 2010-2014
Stichting Wetsus Centre of Excellence for Sustainable Water Technology	10
CSK Food Enrichment B.V.	8
Gebr. Meijer St. Jabik B.V.	5
Lankhorst Engineered Products B.V.	5
BD Kiestra B.V.	4
Dutch Water Technologies B.V.	4
U-sea Beheer B.V.	4
Huhtamaki Nederland B.V.	4

A.S. Oosterhuis Beheer B.V.	3
Astrea Intellectueel Eigendomsrecht B.v.	3
Mustad Netherlands B.V.	3
STERTIL B.V.	3
Paques B.V.	3

Table 20: Overview of Frisian companies who were granted 3 patents or more in the period 2010-2014.

Finally, an overview has been put together based on the different IPC classes, to provide more insight into the different kinds of patents that were requested. IPC classes are codes that inform about the kind of technology that the patent describes. To create a clear overview, the IPC classes are reduced to 3 digits. The matching descriptions and their frequency have been displayed for a total of 10 years (see table 21). It is again noticeable that the patents are related to the water technology sector, have a high score. The clear number two is related to agriculture and the food industry. Note, a patent can have multiple IPC classes, these tables provide a global overview of the most important technology classes.

IPC 3-digit class	Total 2005-2014	IPC class labels
C02	87	TREATMENT OF WATER, WASTE WATER, SEWAGE, OR SLUDGE
A23	54	FOODS OR FOODSTUFFS; THEIR TREATMENT, NOT COVERED BY OTHER CLASSES
H01	51	BASIC ELECTRIC ELEMENTS
B29	44	WORKING OF PLASTICS; WORKING OF SUBSTANCES IN A PLASTIC STATE IN GENERAL
C12	44	BIOCHEMISTRY; BEER; SPIRITS; WINE; VINEGAR; MICROBIOLOGY; ENZYMOLOGY; MUTATION OR GENETIC ENGINEERING
A01	40	AGRICULTURE; FORESTRY; ANIMAL HUSBANDRY; HUNTING; TRAPPING; FISHING
B66	38	HOISTING; LIFTING; HAULING
B01	36	PHYSICAL OR CHEMICAL PROCESSES OR APPARATUS IN GENERAL
G01	36	MEASURING; TESTING
B65	33	CONVEYING; PACKING; STORING; HANDLING THIN OR FILAMENTARY MATERIAL
B62	31	LAND VEHICLES FOR TRAVELLING OTHERWISE THAN ON RAILS
B32	28	LAYERED PRODUCTS
E04	26	BUILDING
F24	26	HEATING; RANGES; VENTILATING
A61	18	MEDICAL OR VETERINARY SCIENCE; HYGIENE

B60	17	VEHICLES IN GENERAL
C08	17	ORGANIC MACROMOLECULAR COMPOUNDS; THEIR PREPARATION OR CHEMICAL WORKING-UP; COMPOSITIONS BASED THEREON
B63	15	SHIPS OR OTHER WATERBORNE VESSELS; RELATED EQUIPMENT
A47	13	FURNITURE
A62	10	LIFE-SAVING; FIRE-FIGHTING
F03	10	MACHINES OR ENGINES FOR LIQUIDS; WIND, SPRING, OR WEIGHT MOTORS; PRODUCING MECHANICAL POWER OR A REACTIVE PROPULSIVE THRUST, NOT OTHERWISE PROVIDED FOR
F16	10	ENGINEERING ELEMENTS OR UNITS; GENERAL MEASURES FOR PRODUCING AND MAINTAINING EFFECTIVE FUNCTIONING OF MACHINES OR INSTALLATIONS; THERMAL INSULATION IN GENERAL

Table 21: Overview IPC classes Frisian patents in the period 2005-2014.

There is a clear increase in the amount of patents with a classification ‘measuring; testing’, compared with the period 2010-2014. Also the major part of patents with the IPC class ‘ships or other waterborne vessels; related equipment’ can be attributed to this period. Patents with the class ‘land vehicles for travelling otherwise than on rails’ and ‘building’ have strongly decreased in comparison to the 5 years before (see table 22).

IPC 3-digit class	Total 2010-2014	IPC class labels
C02	35	TREATMENT OF WATER, WASTE WATER, SEWAGE, OR SLUDGE
G01	28	MEASURING; TESTING
A01	27	AGRICULTURE; FORESTRY; ANIMAL HUSBANDRY; HUNTING; TRAPPING; FISHING
A23	25	FOODS OR FOODSTUFFS; THEIR TREATMENT, NOT COVERED BY OTHER CLASSES
H01	22	BASIC ELECTRIC ELEMENTS
B01	21	PHYSICAL OR CHEMICAL PROCESSES OR APPARATUS IN GENERAL
B29	21	WORKING OF PLASTICS; WORKING OF SUBSTANCES IN A PLASTIC STATE IN GENERAL
C12	20	BIOCHEMISTRY; BEER; SPIRITS; WINE; VINEGAR; MICROBIOLOGY; ENZYMOLOGY; MUTATION OR GENETIC ENGINEERING
B66	16	HOISTING; LIFTING; HAULING
A61	13	MEDICAL OR VETERINARY SCIENCE; HYGIENE
B63	13	SHIPS OR OTHER WATERBORNE VESSELS; RELATED EQUIPMENT
B65	13	CONVEYING; PACKING; STORING; HANDLING THIN OR

		FILAMENTARY MATERIAL
B60	11	VEHICLES IN GENERAL
B62	11	LAND VEHICLES FOR TRAVELLING OTHERWISE THAN ON RAILS
E04	10	BUILDING

Table 22: Overview IPC classes Frisian patents in the period 2010-2014.

It can be concluded that there is relatively little R&D among Frisian companies. This is partly explained by the absence of a Frisian university and the high percentage of SMEs, which often do not have a separate R&D department. Most of the patents are requested in the sector water technology and the food and processing sector.

Appendix 9 - Wetsus

Wetsus is a knowledge institute in Leeuwarden with a research focus on sustainable water technology. Wetsus coordinates a research program to which over 100 private institutions are affiliated. Wetsus has a unique independent position, enabling it to perform multiple national and international research projects, composed by the affiliated private and public organisations. Figure 13 displays an overview of the total number of scientific publications of Wetsus per year. As can be seen there is a reasonably constant growth in the amount of publications since it's founding in 2003.

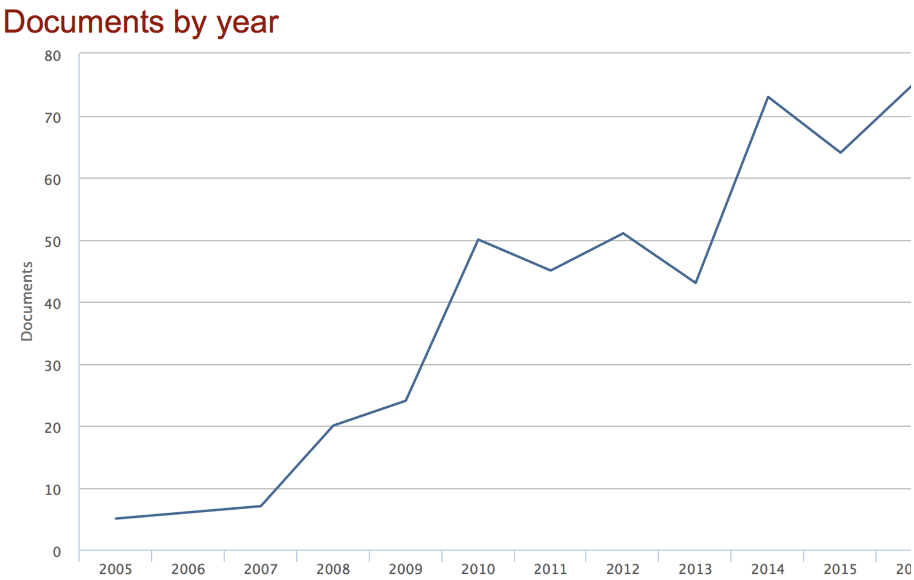

Figure 13: number of scientific publications Wetsus per year (Scopus, 2016).

In the area of knowledge development in the field of water technology in the Netherlands, Wetsus is one of the most visible institutions together with the universities of Delft and Wageningen. To put this in perspective, a comparison is made based on the most prevalent keywords in publications of Wetsus with publications of other Dutch research institutions that contained of one or more of these keywords (see figure 14). The keywords were: "biofouling, desalination, ion exchanges, membranes, water filtration, reverse osmosis, electrodialysis, biofilms, nanofiltration".

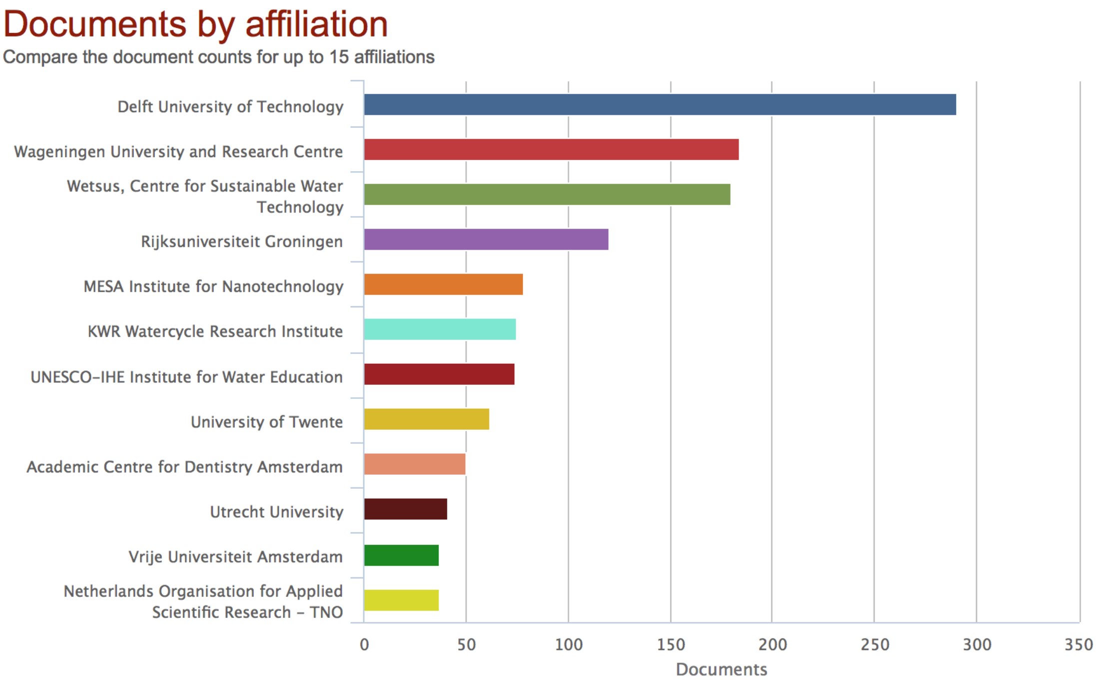

Figure 14: Overview of the knowledge production in the Netherlands within the water technology sector.

Collaborations Wetsus

A way to compare the amount of knowledge exchange is to make an overview of the collaborations on scientific articles. Figure 15 displays an overview of the collaborations for scientific research by Wetsus for over 477 scientific articles, based on the co-authors named at each scientific publication. Using this method, an overview arises to the collaborations of Wetsus over the past 12 years.

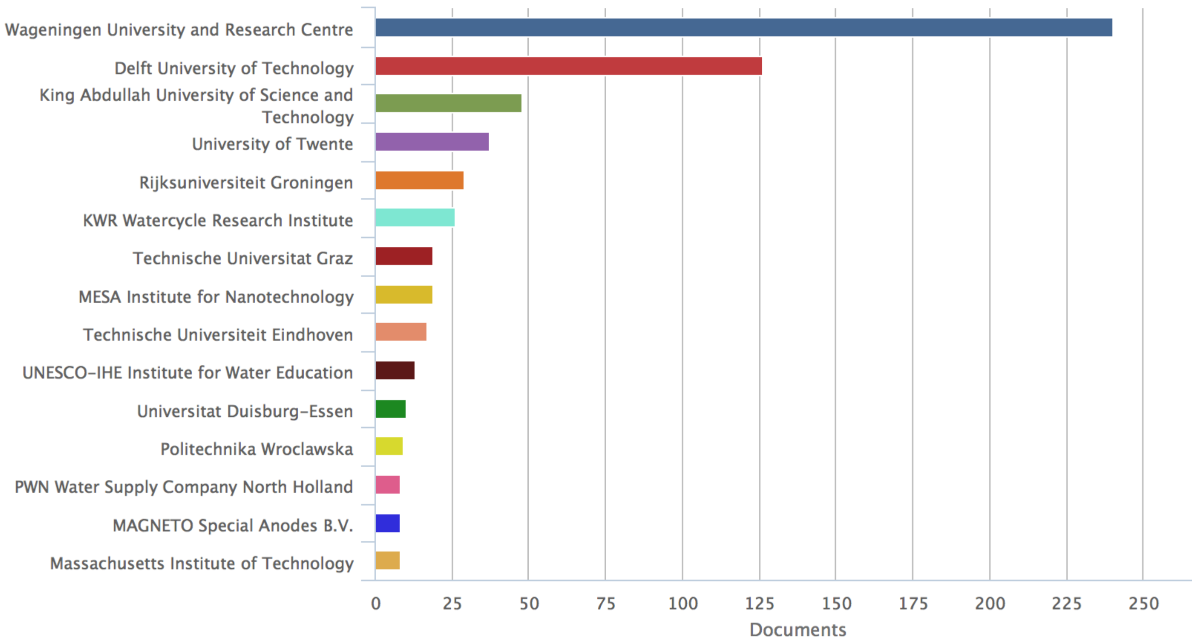

Figure 15: Co-authors of scientific publications to which researchers of Wetsus have contributed since 2002 (Scopus, 2016).

Furthermore, an overview is provided of the collaborations of Wetsus over the period 2015-2017 (see figure 16). On the basis of these two figures, an estimate can be made whether the most frequent research partners in the last two years deviate from those since 2005. This relative short period of two years has been chosen, because Wetsus has worked with 153 scientific publications within those two years alone.

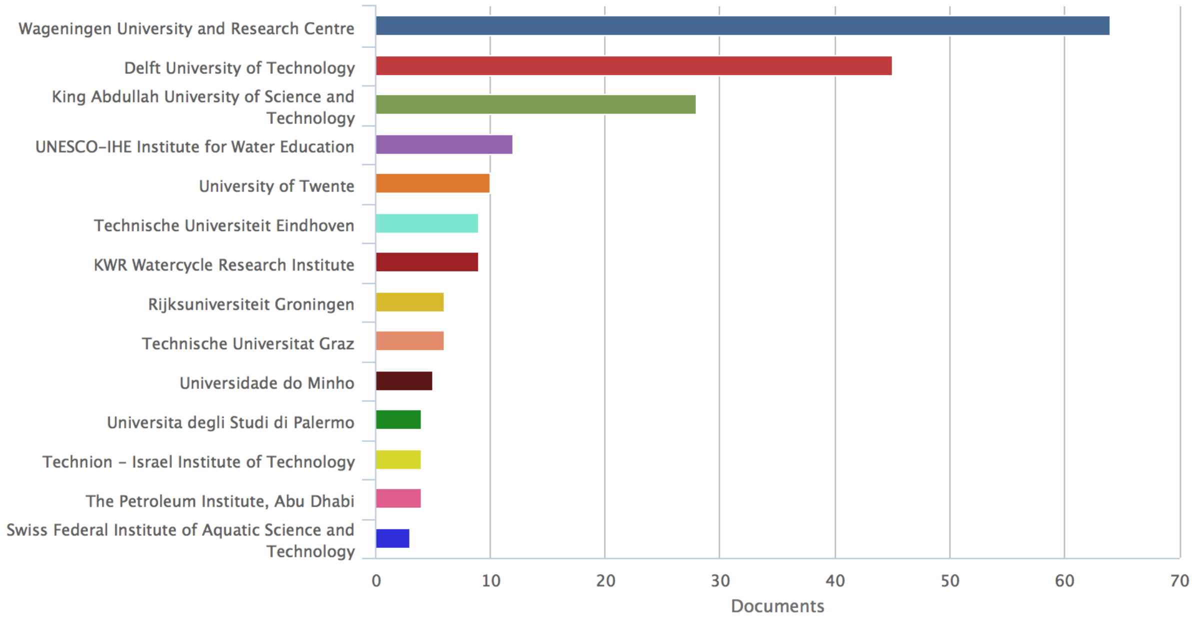

Figure 16: Co-authors of scientific publications to which researchers of Wetsus have contributed since 2015 (Scopus, 2016).

From the figures it can be concluded that the collaborations take place mainly between universities and knowledge institutions. Besides, the most important partners for research have remained the same since the founding of Wetsus.

With regard to knowledge exchange between other sectors, it's more difficult to acquire an accurate estimation, since no scientific publications are available from these clusters. Therefore the interviews will be used to get an overview of the knowledge exchange in the other clusters.