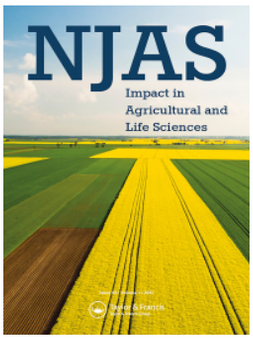

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The influence of the cross-border innovation environment on innovation processes in agri-food enterprises – a case study from the Dutch-German Rhine-Waal region

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ABSTRACT

Enterprises of the agri-food and other sectors develop innovations that can serve the EU's Green Deal objective to become climate-neutral by 2050. Innovation processes face specific innovation environment conditions, which are beyond the enterprise's control. Our research aims to investigate how the innovation environment affects product innovation processes of agri-food enterprises located in a cross-border region. We developed our conceptual framework of the "cross-border innovation environment" based on innovation system and innovation management literature. We conducted semi-structured interviews in selected agri-food enterprises in the Dutch-German region Rhine-Waal. Results indicate that agri-food enterprises' innovation environments concentrated on national-level factors, and that cross-border factors and relationships were rare. Moreover, different factors influenced different stages of innovation processes that were primarily driven by markets compared to research. We conclude that integrating customers and business partners during research and technological development is important to address current challenges of the Green Deal. Understanding how the innovation environment influences innovation processes in agri-food enterprises can help to develop appropriate policies.

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KEYWORD Innovation process; innovation environment; cross-border region; innovation history

1. Introduction

The agricultural sector in the European Union (EU) faces tremendous challenges to address greenhouse gas emissions, loss of biodiversity, soil

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degradation, and groundwater pollution. The EU launched the Green Deal action plan to foster the development of a circular economy through financial and technical support (European Commission, 2019a). Meeting the goals set by the EU Green Deal will require farmers and agri-food enterprises to adapt current practices, increase their resource use efficiency and reduce the environmental impact. Innovation is one pathway towards achieving the goals set by the EU Green Deal. The EU and national governments support this pathway through funding programmes and research projects.

Enterprises – in rural areas specifically small- and medium-sized enterprises (SMEs) – are driving innovation (Noronha Vaz et al., 2004), but not all innovations make it to the market, let alone become successful (Ahmed & Shepherd, 2010). We define innovation as "an evolutionary and social process of collective learning" (Edquist, 2006), which is facilitated by networks of actors (Tranos, 2014). This definition covers the dynamic process of product innovations of the agri-food sector. Hence, innovation processes and their outcomes are influenced not only by internal factors (e.g. creativity, technological capability, or organizational structure) but also by external factors, i.e. the national innovation environment (e.g. the financial system, existing infrastructure, and demand conditions) (Galanakis, 2006). While enterprise performance depends mainly on internal factors which the enterprise can largely control, the national innovation environment also has an effect on enterprises but is beyond their direct control and determined by the location of the enterprise in a specific region (Niebuhr et al., 2020). In the EU, local, regional, national but also supranational institutions shape the innovation environment of agri-food enterprises. Consequently, innovation environments are more complex in particular for enterprises located in a cross-border region, as the jurisdiction in such regions is typically fragmented between two or more different authorities (Guo, 2012).

Cross-border regions cover border regions of two or more neighbouring countries (Perkmann & Sum, 2002). The EU defines border regions at NUTS3 level as the regions within a 25 km zone falling on either side of the border (European Commission, 2017). Contiguous NUTS3 regions from both sides of the border can form cross-border regions as a territorial unit eligible for territorial cooperation programmes such as the Interreg programme (Perkmann & Sum, 2002). In the past, administrative offices evolved in some cross-border regions that do not always match the areas defined by the NUTS classification. Specific cross-border administration offices can take over the management and the strategic development of cross-border regions in the EU.

A cross-border location can affect the innovation processes both positively and negatively: cross-border regions offer enterprises opportunities for business development, because of their proximity to a potential new market, additional market knowledge, sources of knowhow, and business contacts

(Makkonen & Leick, 2019; Smallbone & Welter, 2012). However, different institutional set-ups, political, economic, and socio-cultural structures may hamper innovation. It may also be more difficult to access universities or to develop interfirm relationships across the border (Lundquist & Trippl, 2013).

The innovation environment affects the innovation processes and subsequent market success (Dziallas & Blind, 2019). Prior research showed that enterprises experienced different needs and problems in each stage of the innovation process (Davids & Frenken, 2018). Yet, only a limited number of studies have focused on the innovation environment factors that affect specific stages of the product innovation process, especially in the early stages (Dziallas & Blind, 2019). Other studies on this topic are limited in scope (Karlsson et al., 2018). Galanakis (2006) is a rare exception, and his so-called "**creative factory concept**" offers valuable insights on factors in specific stages of the innovation process. However, an important aspect less emphasized in this concept is the role of different external actors in innovation processes.

Innovation system literature stresses the importance of cooperation for innovation success (Edquist, 2006; Lundvall, 2010; Nelson, 2010). Innovation processes benefit if enterprises are embedded within a strong network and can cooperate along and across the supply chain (Carvalho & Gomes, 2017). Enterprises already experience difficulties to establish contacts with external actors within their national context (Tödtling & Kaufmann, 2002), while cooperating in a cross-border region is even more difficult (González-Gómez & Gualda, 2016; Leick, 2011). This is particularly true for agri-food product innovations (Lefebvre et al., 2015).

Three literature reviews identified significant gaps in cross-border research. A literature review on the development of cross-border clusters found limited research on creating cross-border relationships (Rohde, 2016). Another literature review on the distribution of disciplines in cross-border research found that only 5% of studies focused on business management and only 1% focused on the agricultural sector (Makkonen & Williams, 2016). A third study concluded that cross-border studies rarely focus on SMEs (Makkonen & Leick, 2019). As a result, little is known to date about how the innovation environment affects agri-food enterprises situated in a cross-border region (Makkonen & Leick, 2019; Makkonen & Williams, 2016). To address this gap, our research aims to investigate how the innovation environment affects product innovation processes of agri-food enterprises located in a cross-border region. Given the importance of product innovations in the agri-food sector are needed for accomplishing the objectives of the Green Deal, we specifically focus on product innovations in our research. In our case study, we conducted interviews with a selection of nine agri-food enterprises in the Dutch-German cross-border region. The results aim to guide

enterprises and policymakers on how to further improve the innovation environment specifically in cross-border regions.

2. Conceptual framework: Cross-border innovation environment

Innovation is commonly defined as an iterative and non-linear process that runs through several stages and is subject to continuous evaluation. However, there is less agreement regarding the definition of concrete innovation process stages (Carbonell-Foulquié et al., 2004; Uecke, 2012). The literature on innovation processes usually describes four to eight different stages which vary by the type of innovation, i.e. product, service, process, etc. (see e.g. Salerno et al., 2015). For example, Tzokas et al. (2004) surveyed managers of manufactural industrial and consumer goods and identified five stages in new product development: idea generation, concept development, business analysis (economic evaluation), product development and market testing and launch (Tzokas et al., 2004). In his "creative factory concept", Galanakis (2006) provided a framework and model which emphasizes the enterprise as the main unit of analysis and divides the innovation process into three stages: idea generation, product design and development, and market entrance.

Innovation processes are influenced by internal and external factors. Galanakis's (2006) "creative factory concept" considers both factor types and hence provides a tool to managers to better understand the consequences of their decisions related to the innovation process. **Internal factors** include creativity, corporate strategy, risk-taking policy, technological capability, organization structure and organizational climate. **External factors** comprise the regulations, financial system, infrastructure, demand conditions, critical mass and physical resources, and knowledge and human resources which Galanakis (2006) called national innovation environment.

In addition to the national innovation environment, innovation processes can be facilitated or impeded by the innovation environment and actors of neighbouring countries. The term "national innovation environment" is deduced from the theory of national systems of innovation (Edquist, 2006; Lundvall, 2010; Nelson, 2010), which discusses the nation's influence on innovation. Enhancements of this theory zoom in on a smaller unit of analysis and focus on a specific sector (Klerkx et al., 2010) or region (Cooke et al., 1997). All innovation system theories acknowledge the important role of cooperation. This can occur among multiple organizations at several spatial scales (Lundvall, 2010) and affects the innovation environment and therefore the enterprises' innovation process (Klerkx et al., 2010). Lundquist and Trippl (2013) developed a concept for a cross-border regional innovation system focusing on the level of integration of innovation environments in bordering countries. This cross-border regional innovation system approach is an

adaptation of the regional innovation system approach and **all influences on enterprises are also applicable at a national level**. Hence, for enterprises located in border regions, the cross-border innovation environment shapes their innovation processes. To investigate how the cross-border innovation environment affects the innovation process, the conceptual framework in our paper combines Galanakis's (2006) "*creative factory concept*" and Lundquist and Trippl's (2013) *cross-border regional innovation system approach*. The conceptual framework is presented in Figure 1 and covers three layers, i.e. the stages of the innovation process, the cross-border innovation environment and the relevant actors.

In the first layer, we distinguish four stages of the innovation process as a funnel, i.e. idea generation, concept development, product development and market entrance (i.e. testing and launch) based on Galanakis (2006) and Tzokas et al. (2004). The second layer represents the cross-border innovation environment derived from different levels of integration in cross-border regional innovation systems (Lundquist & Trippl, 2013). The third layer contains important actor categories (Bansal & Grewatsch, 2020; Spendrup & Fernqvist, 2019).

In the cross-border innovation environment, cross-border integration depends on socio-cultural proximity (SCP), accessibility (ACC), science and knowledge bases (SKB), institutional set-up (ISU), economic structure (EST), policy structure (PST), interfirm relationships (IFR) and nature of linkages (NOL) (Hekkert et al., 2007; Lundquist & Trippl, 2013; Trippl, 2010). *Socio-cultural proximity* refers to the relation between the norms, values and cultures (Hermans et al., 2015). Business culture may vary across regions and countries, and if unfamiliar with the local customs, the communication with actors from across the border can become difficult and consequently influence the quality of and interest for cooperation. *Accessibility* (or physical proximity) considers any infrastructural barriers (Klein Woolthuis et al., 2005; Lundquist & Trippl, 2013), as the distance to potential partners and between markets determines how and with whom enterprises operate. *Science and knowledge bases* are important as facilitators of common development and diffusion of knowledge (Hermans et al., 2015). As such, education and research institutes can help enterprises in overcoming barriers or obstacles during the innovation process. *Institutional set-up* refers to alignment of laws and regulations in cross-border regions (Lundquist & Trippl, 2013; Trippl, 2010). During an innovation process, enterprises have to consider regulatory requirements of the potential future market. The *economic structure* addresses the influence of available market structures: competition, information services (Hermans et al., 2015), the structure of the supply chain (Trippl, 2010) and the presence of niche markets (Hekkert et al., 2007). *Policy structure* denotes how the political system, governance structures and modes of operation (casual cooperation vs. coherent strategy) might influence an enterprise's innovation process (Hermans et al., 2015; Lundquist & Trippl, 2013; Trippl, 2010).

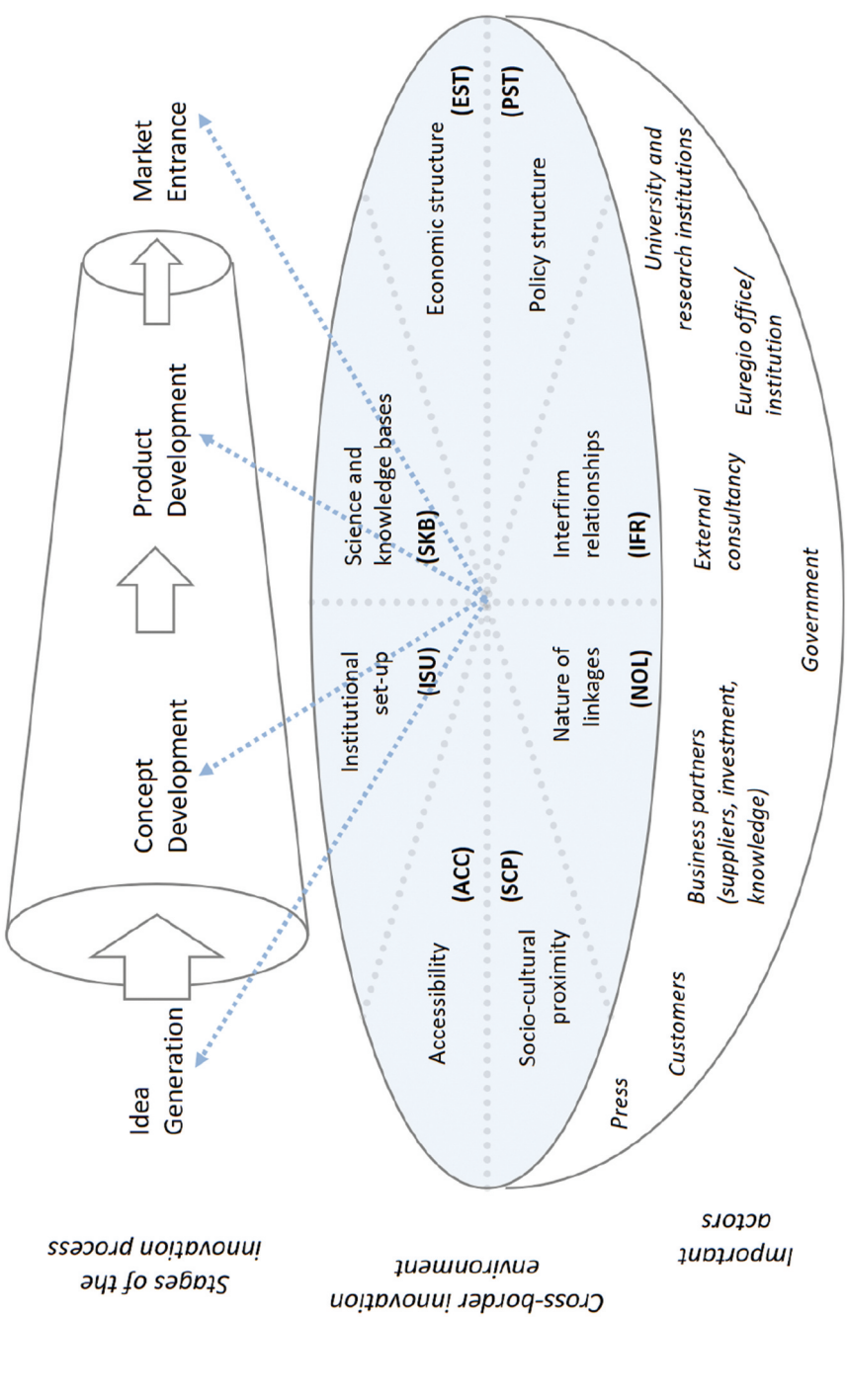

Figure 1. Conceptual framework to investigate the influence of the cross-border innovation environment on specific stages of the innovation process (adopted from Bansal and Grewatsch, 2020; Galanakis, 2006; Hekkert et al., 2007; Lundquist and Trippl, 2013; Neuberger et al., 2021; Spendrup and Fernqvist, 2019; Trippl, 2010; Tzokas, Hultink and Hart, 2004).

Interfirm relationships refer to the interaction between actors at different levels, both within and outside of the enterprise. Innovation can be best stimulated if innovation teams work together with external actors (Bansal & Grewatsch, 2020). External actors can include customers (including farmers, private persons, or other agri-food enterprises), business partners (including suppliers), education and research institutes and other regional actors, e.g. local or national governments, the chamber of industry and trade or the agricultural chamber (Fort et al., 2004; Hermans et al., 2015; Klein Woolthuis et al., 2005). Important actors in cross-border regions can be Euregio or Interreg offices, which try to facilitate cross-border relationships. The collaboration between different actors can encourage knowledge development, mobilize resources and counteract resistance to change, thereby catalysing innovation adoption (Hekkert et al., 2007; Klein Woolthuis et al., 2005). The *nature of linkages* further describes established relationships. Linkages can be driven by costs or knowledge exchange, and be mutual or one-sided (Hekkert et al., 2007; Lundquist & Trippl, 2013; Trippl, 2010).

The conceptual framework presented in Figure 1 allows identifying both positive and negative factors at the national and cross-border level that have an impact on each stage of the innovation process. According to the "creative factory concept", for idea generation and concept development, an enterprise's success and corporate strategy depend (amongst others) on financial systems (i.e. funding), on knowledge and on human resources. During product development, the influence of the innovation environment may lead to adaptations in the innovation process. Hence, it is common to switch back and forth between the concept development and product development stages to adjust the product before entering the market (Galanakis, 2006; Tzokas et al., 2004). For market entrance, infrastructure, demand conditions and critical mass (i.e. customers) affect the success of a new product on the market (Galanakis, 2006). Different actors can further facilitate and impede the factors of the cross-border innovation environment. In our research, we apply the conceptual framework of the "cross-border innovation environment" to investigate agri-food innovation processes in the Dutch-German cross-border region Rhine-Waal.

3. Material and methods

We conducted a case study with interviews (Yin, 2009) to ex-post evaluate innovation processes (Wittmayer et al., 2015). The Social Sciences Ethics Committee of Wageningen University reviewed and approved this research before data collection started (No. 09215846).

3.1. Case study region

Our research was carried out in the Dutch-German cross-border region, more specifically the Euregio Rhine-Waal. The dedicated goal of the Dutch-German cross-border region (Euregio Rhine-Waal, Ems Dollart Region, the Euregio (Gronau) and the Euregio Rhine-Maas-Nord) is to increase innovation and decrease practical hurdles (Sekretariat, 2021). Therefore, EUR 440 million was made available between 2014 and 2020 to support cross-border cooperation in different sectors, e.g. health, security, education and industry, through the European Fund of Regional Development (EFRD) with its INTERREG funding programme. The Interreg funding programme focuses on supporting small and medium enterprises.

The Euregio Rhine-Waal covers an area of 8,663 km^2 and extends over the Dutch areas of Achterhoek, Gelderland, the north-east of Noord-Brabant, and Noord-Limburg and the German areas of Kleve, Wesel, Duisburg and Dusseldorf. This cross-border region has 4.2 million inhabitants and 22 universities and universities of applied sciences (8 in Germany and 14 in the Netherlands) are located there (Waal, 2020a). Furthermore, the Euregio Rhine-Waal is one of the most innovative regions in Europe (European Commission, 2019b). Between 2008 and 2020, 177 projects were initiated and funded by Interreg, and recently finalized projects are e.g. Regional Skills lab, Digi Pro or Food Pro-tec-ts.

The Euregio Rhine-Waal has an administrative office which is situated in Kleve. Such administrative offices evolved historically and are not present in every cross-border region in the EU. Hence, the Euregio Rhine-Waal may have an advantage over other Euregio regions in fostering cooperation between municipalities and inhabitants across the border. The Euregio Rhine-Waal was actually the first cross-border public-law special administrative unit in Europe (founded in 1993), although cross-border interaction can already be dated back to 1963 in the Dutch-German cross-border region (Waal, 2022). The Euregio Rhine-Waal consists of 55 member organisations, and 3 committees (i.e. cross-border understanding, economy, and finance and projects) advise the Euregio board (Waal, 2022). The strategic agenda 2025+ summarizes four cross-border regional challenges: (1) economy and climate, (2) labour market and education, (3) quality of life and (4) euregional identity (Waal, 2020b).

Nevertheless, Camagni et al. (2019) uncovered unused economic potential in this cross-border region. Furthermore, there is an urgent need for agricultural innovation, as intensive agricultural production systems and unsustainable resource use lead to environmental problems, such as high ammonia concentrations in groundwater and surface water bodies (Smit et al., 2015; Westfalen, 2021). Farmers in the Dutch and German parts of the Euregio Rhine-Waal need to adapt their farming practices to address these environmental challenges. The need for improved production techniques in the agri-food sector also

opens business opportunities for enterprises in the region. These circumstances make the Euregio Rhine-Waal an interesting case to study.

3.2. Selection criteria of enterprises and innovation processes

We selected nine enterprises which (1) were located in the Euregio Rhine-Waal, (2) had experience in cross-border cooperation and (3) were working on an innovation process (4) in the agri-food sector. While all selected enterprises were working on product innovations, their location varied (Germany vs. the Netherlands) providing a variety of contexts in line with our conceptual framework.

We contacted enterprises using a stepwise approach. First, we identified potential interviewees among the participants of the Food Pro-tec-ts research project, which aimed to promote specific product and process innovations in the agri-food sector in the Euregio Rhine-Waal. Additionally, potential participants were addressed through snowballing and during networking events. We contacted the enterprises by mail followed by a short telephone survey. The short survey template covered twelve questions to identify whether the enterprise met the requirements and to enable the later comparison between the cases (see Table A in the supporting information). Second, upon meeting our requirements, we scheduled face-to-face appointments and conducted semi-structured interviews. In total, nine interviews were conducted: five with interviewees from Dutch enterprises and four with interviewees from German enterprises. Eight enterprises participated in the Food Pro-tec-ts project, and one additional enterprise was recruited during a networking event. Table 1 presents an overview of these enterprises.

3.3. Innovation histories

Innovation histories consist of an innovation timeline and an actor-network map and offer an inductive and heuristic approach to understand the innovation process (Wittmayer et al., 2015). Following the method of an event history analysis, researchers try to make sense out of past events which occurred during the innovation process (e.g. Hermans et al., 2019). In the context of our research, events are defined as events with any influence on the innovation process, e.g. participation in staff and project meetings, access to funding, access to education and research facilities, or relationships to customers and suppliers.

Whereas data collection for the innovation histories is usually done through group interviews, in our research we conducted individual interviews, as only a few people were responsible for the innovation processes in the selected enterprises. Following Creswell (2014), we developed a codebook based on the conceptual framework (Figure 1) prior to conducting the interviews. The qualitative codebook consisted of three themes:

Table 1. Overview of selected enterprises: Innovation processes driven by customers or business partners (MAR); innovation processes driven by university and research (RES).

Enterprise Case No.		Name of innovation	Aim of innovation	Potential final customers	Current stage of innovation process	Size of enterprise*	Country	No of people working on innovation process	Founding year of enterprise	Starting year of the innovation process
Market-driven innovation processes (MAR)										
MAR	1	Asparagus harvester	Increasing resource efficiency and improving the quality of harvested asparagus *through sub-surface detection of asparagus;* Independence from co-workers	Farmers	Product development/ Market entrance	Small	NL	19	2014	2013
MAR	2	Barn climate control sensors	Improving animal welfare (and the quality of meat) *through access to information on the barn climate and hence improved herd management*	Farmers	Market entrance	Medium	NL	3	2007	2016
MAR	3	Reptile feed	Increasing resource efficiency *by processing insects for non-refrigerated reptile pet feed*	Pet shops, reptile owners	Market entrance	Small	NL	10	2012	2017
MAR	4	Struvite fertilizer	Increasing resource efficiency *through upcycling of industrial waste streams for fertilizer production*	Farmers	Product development/ Market entrance	Medium	GER**	3	1954 (NL), 2004 (DE)	2014
Research-driven innovation processes (RES)										
RES	1	Plasma technology for odour control	Decreasing odour emissions from livestock stables (to meet regulatory standards) *by adapting plasma technology for odour control*	Farmers	Product development/ Market entrance	Small	NL	3	2014	2018

(*Continued*)

Table 1. (Continued).

Enterprise Case No.		Name of innovation	Aim of innovation	Potential final customers	Current stage of innovation process	Size of enterprise*	Country	No of people working on innovation process	Founding year of enterprise	Starting year of the innovation process
RES	2	Surface texture technology (meat) - *Sensors*	Improving food safety *by analysing the surface texture of meat and meat products to detect microorganisms*	Meat industry	Concept development	Small	GER**	3	-	2017
RES	3	Surface texture technology (meat) - *Laboratory tests*	Improving food safety *by analysing the surface texture of meat and meat products to detect microorganisms*	Meat industry	Concept development	Medium	GER	4	1996	2017
RES	4	Hydrothermal carbonization	Increasing resource efficiency in waste recovery systems *through hydrothermal carbonization*	Farmers, larger communities (e.g. villages)	Market entrance	Micro	GER	2	2009	2006
RES	5	Surface texture technology (meat) – *Industrial use*	Improving food safety *by analysing the surface texture of meat and meat products to detect microorganisms* (improved surface of machine equipment)	Meat industry	Concept development	Medium (NL), Large (world)	NL**	5	1967 (2007 trans-formation)	2012

*Micro (<10 employees), small (10–49), medium (50–249) and large firms (>250) (OECD, 2021).** Enterprise is located in Germany and the Netherlands, and the country is the main location for conducting the innovation process (in line with the interviewee's main location)

Table 2. Codebook (derived from Figure 1).

	Theme	Code
1	Stages of the innovation process	Idea generation Concept development Product development Market entrance
2	Cross-border innovation environment[i]	SCP: socio-cultural proximity ACC: accessibility ISU: institutional set-up SKB: science and knowledge bases EST: economic structure PST: policy structure IFR: interfirm relationships NOL: nature of linkages EXF: external funding[ii]
3	Evaluative nodes	(+) Positive[iii] (–) Negative[iv]

[i] For the sake of completeness, data on the firm-internal factors (e.g. firm management, firm capabilities) was collected but initial analysis found low variance between the enterprises, hence they were excluded from further analysis.

[ii] Galanakis, (2006) stated that financial systems, next to knowledge and human resources, are part of a firm's success and corporate strategy and hence are internal factors. However, access to external funding turned out to be an important topic for firms in our sample. We therefore decided to add the code 'External funding' (EXF) to identify its influence in the cross-border innovation environment as presented in the conceptual framework above.

[iii] A factor was coded as positive, if the respondent made clear that the event had a facilitating role in the innovation process.

[iv] A factor was coded as negative, if the respondent made clear that the event was hampering or inhibited the innovation process.

stages of the innovation process, the cross-border innovation environment and evaluative nodes (Table 2). The codebook helped to develop the semi-structured interview questions (Creswell, 2014) and to structure these questions on a template. The interview template was designed in the style of a timeline and covered the stages of an innovation process and two thematic segments: (a) events that facilitated or impeded the innovation process, and (b) the actors involved. A pre-test was conducted in July 2019 whereupon minor adjustments of the interview questions were made.

Prior to starting the interview, we described the purpose and the objectives of our research. We showed the drafts of the research protocol, explained the research process, the consent form and data treatment, and that the respondents were free to quit the interview anytime. We asked interviewees to recall what affected the innovation processes and noted keywords on the template visible for the interviewee. The interview finished with developing the actor-network map as part of an iterative process to recall relationships and hence to reduce the potential drawback of using a linear innovation process timeline. Written informed consent was collected from all respondents at the end of their interviews.

The interviews lasted between 25 and 75 minutes. Interviews were recorded, transcribed and summarized. Recording was not possible or not

permitted during the three interviews. In these cases, notes were summarized in an extended form sent to the interviewee for validation and clarification. A summary of the recorded interview was also sent to the interviewees for approval.

Interview analysis was based on the codebook (Table 2) using the qualitative data analysis software NVivo 12. Every event (i.e. factor) was coded along the three themes of the codebook.

4. Results

Our study on the Dutch-German cross-border region Euregio Rhine-Waal demonstrates that external factors can occur in every stage of the innovation process. During the analysis of results, we found marked differences between innovation processes that were primarily driven by customers or business partners (i.e. the market) and innovation processes driven by universities (i.e. research). Therefore we first present the results for market-driven innovation processes (MAR1, MAR2, MAR3, MAR4) in a combined innovation history (Figure 2), followed by the combined innovation history of research-driven innovation processes (RES1, RES2, RES3, RES4, RES5, Figure 3). In both figures, we highlight the cross-border influence by an asterisk. A full description of the innovation histories is available as supporting information.

4.1. Market-driven innovation processes

Four innovation processes were driven by customers, such as farmers (MAR1, MAR2), and business partners along the supply chain (MAR3, MAR4). The combined innovation history is presented in Figure 2. The innovation processes concentrated on solving concrete problems of the agricultural sector: improving the quality of harvested asparagus, improving animal welfare (and the quality of meat) and increasing the efficiency of resource use by processing insects for non-refrigerated reptile pet feed or by upcycling industrial waste streams for fertilizer production (see Table 1).

The main influence of the innovation environment stemmed from inter-firm relationships with customers, business partners and later also universities. During the **Idea Generation** stage, all four enterprises concentrated on involving their potential future customers and established test groups – upon the enterprises' final decision to continue working on the idea $^{(IFR)}$ (see Table 1 for an overview of potential customers). One enterprise immediately initiated customer test groups in both countries (MAR1). All four enterprises maintained the relationships to their test groups during the whole innovation process, including market entrance, and considered them as very important. Three out of the four enterprises were already established businesses and

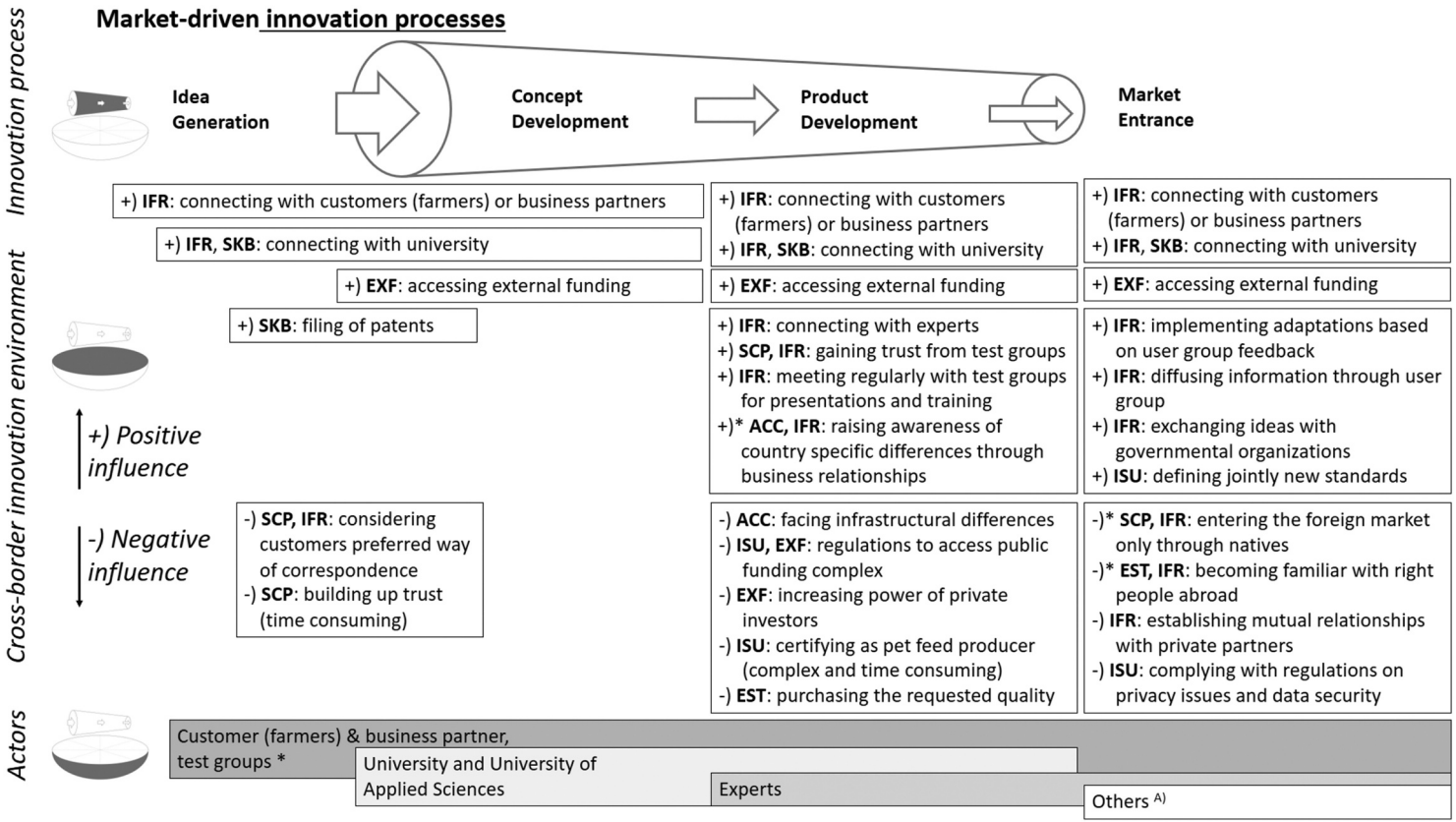

Figure 2. Combined innovation history of innovation processes driven by customers (farmers) or business partners. (own elaboration based on interviews with MAR1, MAR2, MAR3, MAR4) *highlights the cross-border influenceA)Others include local institutions such as the Agricultural Chamber of North-Rhine Westphalia (LWK NRW) and the Interest Group Cross-Border Integrated Quality Assurance (GIQS).

could progress from idea generation to concept development without any external financial assistance (MAR2, MAR3, MAR4). However, in one case, idea generation occurred prior to the enterprise started up and hence financial resources had to be mobilized before moving on to concept development (MAR1). An early relationship to a university helped to acquire financial resources through research projects (MAR1) (SKB, IFR). Enterprises valued universities as important partners but not as the initial drivers. However, the filing of patents was an important step before engaging with any partner or the public, e.g. to raise funding (MAR1) (SKB).

During **Concept Development**, the other three enterprises (MAR2, MAR3, MAR4) also developed relationships with universities to assist in research activities (SKB, IFR). These relationships were essential to gain access to laboratories and students (MAR1, MAR3, MAR4) (SKB), but sometimes perceived as challenging because establishing mutual trust was time-consuming (MAR1) (SCP). All four enterprises initiated regular customer group meetings and maintained a close interfirm relationship with customers during the product development stage (IFR). At this point of the innovation process, enterprises' continuous search for funding started and continued to have an important role throughout the whole innovation process (MAR1, MAR2, MAR3, MAR4) (EXF). Access to external funding facilitated development and market launch (MAR3) (EXF).

During the concept development stage, the enterprises had to invest in the relationships with their respective test groups. Although resources were scarce, one enterprise had to adjust its communication to farmers by constructing an actual machine prototype (MAR1) (SCP). The development of such a tangible prototype increased the engagement of the test group to provide feedback on the ongoing machine development (IFR); however, farmers also wanted to receive something in return for their engagement, resulting in continuous relationship investments by the enterprise (MAR1).

During **Product Development**, test group relationships helped enterprises to continuously adjust the product to market needs. Enterprises finally benefitted from the gained trust of the test groups and the long-term effect of the established relationships finally showed results (MAR1) (SCP, IFR). One enterprise valued the mutual engagement of partners (MAR2) (NOL) and the product development stage was positively affected through regular meetings with and training of test groups – in both countries (MAR1) (IFR). The network was further extended because experts were consulted, e.g. to interpret the collected data (MAR2) (IFR).

Enterprises faced obstacles regarding funding, infrastructure, institutional set-up and economic structure during the product development stage. The importance of financial support grew in this stage, because enterprises had to develop, test and further adjust the prototype (MAR1, MAR2) and access to funding provided a big push because e.g. new staff could be hired (MAR3,

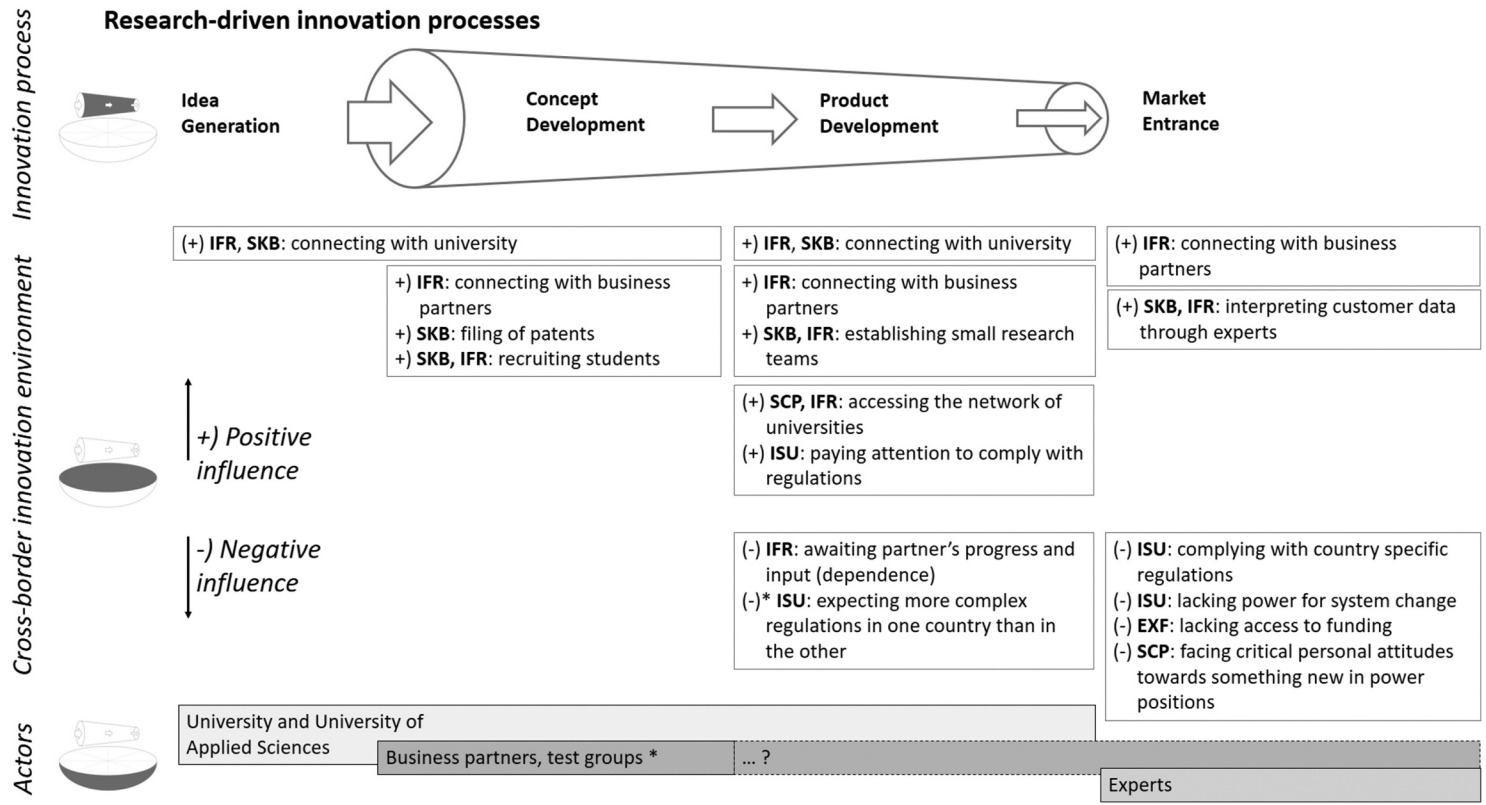

Figure 3. Combined innovation history of innovation processes driven by university and research. (based on interviews with RES1, RES2, RES3, RES4, RES5).

MAR4) (EXF). However, winning private investors also meant handing over decision-making power to the investor (MAR1) (EXF) and the regulations to access public funding were considered rather complex (MAR1) (ISU, EXF). Other obstacles experienced at this stage were of bureaucratic nature, i.e. the certification as a pet feed producer (MAR3) (ISU), and of economic nature, i.e. delivery problems along the supply chain (MAR3) (EST). Solving these issues was time-consuming. At an early stage of product development, the customer test group of the foreign country drew the enterprise's attention to the existing infrastructural differences (i.e. different connections of the sensors with the internet) and hence these differences could be considered during product development (MAR2) (ACC, IFR).

During the **Market Entrance** stage, innovation processes were heavily influenced by the relationships to the test groups and other experts. The test groups provided feedback to adapt the product (MAR3), and also helped to raise attention and to diffuse information about the innovation among other potential future customers (MAR1) (IFR). The experts' networks also helped to promote the product and the press was identified as yet another important actor to draw the customers' attention to the innovation (MAR2) (IFR). The attention was also brought forth by the relationship to local institutions such as the Agricultural Chamber of North-Rhine Westphalia (LWK NRW) and the Interest Group Cross-Border Integrated Quality Assurance (GIQS) (MAR2). However, a relationship to the market across the border was partly missing because enterprises lacked the right network (governments and actors along the supply chain) (MAR3) (EST, IFR). Enterprises shared the opinion that cross-border relationships were difficult to initialize and that they needed a native employee to develop such relationships and to promote the innovation in the other country because of language issues (MAR1, MAR2, MAR3, MAR4) (IFR, SCP). Two enterprises (MAR1, MAR2) could establish a good network in both countries and could benefit from mutual exchange of knowledge and experience (IFR, NOL).

Enterprises experienced obstacles regarding the institutional set-up during the market entrance stage. Launching a new product on the market forced enterprises to deal with the existing regulations on privacy and data security (MAR2), or with a complete lack of a regulatory framework (i.e. for the production of insects) (MAR3). In this specific case (MAR3), the absence of laws provided the enterprise with the opportunity to define new standards (i.e. for insect production) (ISU). Because of the established relationships, enterprises seemed more aware of potential obstacles concerning different or absent regulations in the two countries and could consider them before the expected market entrance.

4.2. Research-driven innovation processes

Three innovation processes were driven by research, of which two innovation processes involved one enterprise each (RES1, RES4) and the third one involved three enterprises (RES2/RES3/RES5). The combined innovation history is presented in Figure 3. The three innovation processes concentrated on the practical implementation of specific scientific achievements: decreasing odour emissions from livestock stables (to meet regulatory standards), increasing the efficiency of resources in waste recovery systems through hydrothermal carbonization and improving food safety by analysing the surface texture of meat and meat products (see Table 1).

Our results showed that in research-driven innovation processes, the relationships with universities were stronger than the ones with customers. Enterprises accessed science-based ideas for their innovation processes through existing relationships with universities (SKB, IFR). During the stages **Idea Generation** and **Concept Development**, the enterprises focused on research and development in collaboration with universities to test the applicability of their idea in practice and to recruit students to work on the innovation process (RES1) (SKB, IFR). One enterprise initiated a customer test group during the concept development stage and developed relationships to business partners in both countries (RES1) (IFR). Unfortunately, this enterprise could not offer further insight into the duration and influence of these relationships because the innovation process did not proceed beyond the concept development stage yet. However, the enterprise indicated to maintain these relationships during product development (as shown by the dotted line in "Actors" in Figure 3). The relationships with universities also affected product development but did not affect the market entrance stage.

During the **Product Development** stage, the innovation processes were almost exclusively determined by national-level factors. For example, existing relationships to universities provided access to their (mainly national) network and thereby facilitated the progress of the innovation process (RES2/RES3/RES5) (SKB, IFR). At this stage, enterprises paid attention to meeting the regulations required for later market entry (RES2/RES3/RES5) (ISU). In this specific case, enterprises planned to introduce the product first in one market (i.e. the Netherlands) as they were more familiar with the regulations and also expected more complex regulations in the other country (i.e. Germany) (ISU).

Enterprises considered research projects such as Interreg as a helpful source of funding, to mobilize resources and to easily connect with actors in the same business sector (RES1, RES4, RES2/RES3/RES5). The Interreg projects allowed enterprises to easily develop a network with business partners in the cross-border region. All enterprises with research-driven innovation processes participated in a publicly funded Interreg research project which might explain why enterprises did not mention access to external

funding being a limiting factor in the innovation processes. However, with an increasing number of universities and business partners involved in the innovation process, the mutual dependence to complete tasks increased as well, causing progress delays (IFR).

Innovation processes with a strong focus on university relationships seemed to result in a disadvantage during the **Market Entrance** stage because universities usually do not have detailed insights in the market of a respective industry. Hence, enterprises perceived the relationship to experts who have such insights in the respective countries as essential to connect with potential customers and to facilitate a later marker launch (RES2/RES3/RES5) (SKB, IFR). At the time our study was conducted, only one of the three investigated innovation processes had reached the market entrance stage (RES4). In this case, the enterprise experienced regulatory obstacles which could have been (partly) resolved if considered earlier (ISU). The enterprise also missed to clearly define their targeted customers and hence the enterprise did not invite customers to analyse their requirements for buying and using the innovation. Due to the complexity of this specific innovation, a wider system change might be necessary to support the market launch of the innovation, but the enterprise lacked the power to initiate such change and hence to motivate customers to adopt the innovation (RES4) (ISU, SCP).

5. Discussion

Our research offers four essential insights into external facilitators and obstacles during innovation processes of agri-food enterprises. First, our research indicates that the influence of cross-border factors on agri-food enterprises' innovation processes was less important than national-level factors. Second, we observed that different factors affect different stages of market-driven compared to research-driven innovation processes. Third, we observed different needs for cross-border cooperation during the innovation process stages. Fourth, enterprises experienced a lack of public support to launch the innovation on the market. These four main findings will be discussed below.

First, in all investigated cases, the majority of external factors stemmed from the national, and not the cross-border, innovation environment. We observed that factors concerning the institutional set-up and economic structure often occurred in the country in which the enterprise was located. Although institutional factors are important for SMEs' business operations (Di Cai et al., 2016), Fichet de Clairfontaine et al. (2015) showed that institutional barriers and geographic distance are less important if cross-border cooperation between university and industry generates scientific output (e.g. publications). However, we only observed few relationships of agri-food enterprises with actors across the border because they perceived the

development of a strong network abroad as difficult (MAR4). Our observation is in line with Tödtling and Kaufmann (2002), who stressed that SMEs already struggle to develop strong networks in a national context. However, research also showed that start-ups can already benefit from cross-border relationships if these are well planned (Dashti & Schwartz, 2018). Hence, cross-border relationships with business partners and actors other than universities are important for the innovation process, but we only know little about how to establish cross-border linkages (Rohde, 2016). Enterprises perceived different mindsets as beneficial for the innovation process (RES1) but similarly to Borges et al. (2021), we observed minor language problems when initiating cross-border cooperation. Enterprises unanimously agreed that a native speaker is essential when the enterprise enters a neighbouring market and starts the diffusion of the innovation.

Second, all the investigated innovation processes were driven by external sources of information, but we observed that different factors affect different stages of innovation processes driven by customers and business partners (i.e. the market) and by university publications (i.e. research). External information can be provided by customers, suppliers, competitors and be derived from publications and patents (Gaubinger et al., 2015; Hippel, 1995).

In the investigated market-driven innovation processes, enterprises engaged with customers from the beginning, and therefore customers could help to develop the product to match their needs. Through the early relationships with customers, enterprises were reminded to take care of specific questions important for the customer group. Hence, customer feedback helped them to adapt the innovation and benefit from the long-term effects of these relationships (MAR1, MAR2). Svare (2016) confirms our finding that interaction with customers and access to their practical knowledge facilitates innovation. However, previous research also suggests that increased coordination costs of different partners can outweigh potential benefits of cooperation (D'ambrosio et al., 2017). In our study, the positive effects on the progress of innovation processes prevailed, although developing interfirm relationships with customer groups was time-consuming and not easy to manage for our selected enterprises. Additionally, we observed that enterprises which addressed customer questions already during product development benefitted when entering the market because time delays due to unmet regulatory requirements did not occur (MAR2, MAR3). Our observation adds to Galanakis' (2006) creative factory concept in that factors of the national innovation environment may cause adaptions of product development.

In the investigated research-driven innovation processes, enterprises started to engage with customers and to consider market needs only when the innovation process had already progressed which restricted the potential benefit of these relationships. For example, MAR3 could adapt the innovation

during the product development stage according to customer input compared to RES4 who experienced difficulties because the innovation was adapted only after market entrance. This observation is in line with D'ambrosio et al. (2017), who found that the duration of a relationship has a higher influence on innovation than the sheer number of actors, and with Apa et al. (2020) and Jong and Slavova (2014), who identified a positive effect of enterprise-university cooperation on the innovation processes. Previous research further suggested that customer-driven innovation processes are predominant in agri-food SMEs while research-based actors do not appear relevant to drive innovation (Lefebvre et al., 2015). We found that universities are also an important actor. However, Živojinović et al. (2017) showed that relationships and networks are not always established equally well, and even though enterprises develop relationships with universities easily, linkages to governmental organizations for innovation support were more difficult to establish (Živojinović et al., 2017). For example, linkages to governmental organizations were only present in market-driven innovation processes (MAR2, MAR3), and enterprises developed relationships to universities easier in research-driven than in market-driven innovation processes. A possible explanation for this difference is that enterprises with research-driven innovation processes had already established some kind of relationship with university researchers before starting to further develop the idea.

Third, the need for cross-border cooperation varies throughout the observed innovation process. During idea generation, market-driven innovation processes were initialized by customer needs and continued within the company and no need for additional cooperation was reported. Research-driven innovation processes were facilitated by a connection between research and an enterprise and a university connection should be based on available competences and not be hindered by the border. Concept and product development is a back-and-forth process and as such, the need for cross-border cooperation may also vary within the stages of the same innovation process. During concept development it is essential to think already about future marketing options. If marketing abroad is not anticipated, then there might be no need for cross-border cooperation (unless specific scientific expertise is required from a university partner at the other side of the border). If marketing abroad is desired in the future, cross-border cooperation options should be considered during concept and production development through e.g. implementing customer test groups in both countries, establishing contacts along the supply chain and building up a network for marketing purposes. MAR1 pointed out that, during product development, they finally benefitted from the effort put into developing test groups in both countries. Understanding your customer is crucial and this research showed that adhering to future demands in the bordering market at an early stage helps to adopt the product to specificities of the other country. Latest during market

implementation in the neighbouring region, cross-border cooperation is necessary for understanding the supply chains and establishing contacts with customers.

Fourth, the enterprises in our case study experienced a lack of support in launching the innovation. We observed that the enterprises working on the three research-driven innovation processes evaluated their participation in research projects as positive for the innovation because they could access a broader set of information, which is in line with D'ambrosio et al. (2017). Similarly, Samara et al. (2020) acknowledged public funding as a good instrument to initiate innovation processes, but also advised public authorities to consider regional needs and priorities to help reduce dependency on public funding. In the context of cross-border regions, it is important to note that access to national funding is mostly restricted to native enterprises and, hence, access to funding abroad is restricted and collaboration with partners abroad is not eligible for funding. Since the majority of the companies in this case study participated in an Interreg project, it is difficult to say what might have prevented others from also participating or applying for other funding. Furthermore, it seemed that other programmes such as Horizion 2020 also did not play a role according to our respondents. This suggests that existing public funding programmes are not being fully exploited by the SMEs investigated in this study. One enterprise considered a major drawback of EU funding that potential market applications of innovations are not thought through at an early stage (RES5). Salerno et al. (2015) suggests that innovation processes driven by public calls for technological development need support to link research developments with market needs and consequently reduce uncertainty early. This is in line with our observation that enterprises working on research-driven innovation processes experienced difficulties to access the market.

In our case study, those enterprises with research-driven innovation processes mainly focused on the practical implementation of research and did not consider market requirements during product development. Hermans et al. (2019) found that enterprises who cooperate with public organizations such as government agencies and universities (i.e. public–private partnerships) are less capable of stimulating functions necessary for the final market development and meeting consumer demands of innovation. Burgelman and Sayles (2009) and Gaubinger et al. (2015) observed that SMEs often lacked strategic management of innovation processes – especially repeated evaluation between the stages which would prevent working on ideas without a market. Such phenomena have extensively been discussed in the literature on push- and pull-innovation (Burgelman & Sayles, 2009). Faced with unmet market requirements, an enterprise was confronted with additional financial and administrative problems while making the necessary adjustments or dealing with regulatory offices (RES4). Our research also found indications

that the economic evaluation of an idea and the assessment of the potential market application of a technology are particularly difficult in the beginning of an innovation process (RES5). However, if innovation processes are not designed to market needs, they could fail regardless of being e.g. the more sustainable or resource-efficient option (e.g. Gaubinger et al., 2015). Enterprises might need other or additional criteria than evaluation according to the stage-gate model to develop and launch sustainable agri-food innovations successfully (Bansal & Grewatsch, 2020). Our observation is in line with Caiazza (2016) who identified a lack of policies and support especially for innovation diffusion.

6. Policy implications

First, our research showed that relationships to customers, business partners and research are important in every stage of the innovation process but influence it in different ways. Potential customers provide valuable feedback during the concept and product development stage but also assist in the diffusion of the innovation. Hence, enterprises are advised to include them already during the early stages of innovation processes and maintain these relationships. If missing, enterprises can initiate to meet potential customers through already established relationships to universities and other business partners. Enterprises' relationships to universities are important at the beginning of innovation processes to foster research-related developments. If missing, enterprises could develop this relationship through an incubator space such as living labs or science and technology parks. Such incubator spaces do not only offer the needed linkages to research and universities, but also provide opportunities for interfirm relationships to evolve. Ubeda, Ortiz-de-Urbina-Criado and Mora-Valentín (2019) showed that the benefits of such a location depended very much on the stage of the SME and the mix of enterprises. Yet, enterprises can always benefit from events organized in such incubator spaces even if not directly located there, e.g. the Brightlands Campus Greenport Venlo offers regular events to engage with research and business partners of the respective field.

Second, our findings suggest that enterprises need more than just financial support for e.g. conducting research in their innovation processes. Capello (2017) questions the adequacy of current EU policies on facilitating innovation and suggests to develop thematically and regionally focused innovation policies. At the same time, policy concepts are becoming rather complex due to a broad conception of innovation (Meissner et al., 2017) and open calls for funding and financial support of innovation processes often concentrate on specific themes. Hence, the political agenda has a significant impact on the main areas of research and therefore

determines which innovation processes will be developed further. However, this does not mean that innovation processes that are in line with the political agenda and meet societal needs such as sustainability or climate change are also successful on the market. Governments or local institutions should (1) provide enterprises with contact to actors of their respective industries (including customers), and (2) encourage enterprises to identify the potential market and to become familiar with market structures during product development to reduce later obstacles (see also Aldieri et al., 2019; D'ambrosio et al., 2017; Svare, 2016; Tödtling & Kaufmann, 2002). In the agri-food sector, many enterprises face difficulties in achieving these quite intuitive requirements, because small enterprises lack managerial skills, have limited profitability, and are more dependent on public funding. Hence it appears more important for these enterprises to study customers' rationale for innovation adoption, and governmental structure can facilitate this process to reach the goals of the EU Green Deal (see also Vanclay et al., 2013).

Especially in cross-border regions, enterprises might need additional assistance when entering non-native markets to facilitate the diffusion of promising innovations. For example, international patent cooperation was more likely to occur when market-based regulations were similar or when market-based strategies were jointly coordinated (e.g. through agreements on taxes and tariffs) (Milani, 2020). Enterprises could reduce this type of obstacles by becoming involved in e.g. formulating standards for insect production (MAR3) (see also Borges et al., 2021).

7. Conclusions

We investigated the influence of the innovation environment on innovation processes in agri-food enterprises in a cross-border region. Our conclusions are summarized along three lines:

First, in a cross-border region, foreign enterprises indicate that cooperation with natives facilitated the innovation processes but that such cross-border cooperation was not easy to establish. Socio-cultural differences had an impact on cross-border cooperation in both market- and research-driven innovation processes. While this factor did not impede research-related activities during concept and product development, foreign enterprises had to make an effort to develop and manage relationships with potential customers and business partners in the other country.

Second, interfirm relationships affected all stages of both market- and research-driven innovation processes. Enterprises' relationships with universities as well as relationships with customers or business partners facilitated the innovation process. While relationships between enterprises and universities seemed to be essential for fundamental research and development of

prototypes during early stages of the innovation process, relationships between enterprise and customers or business partners had a major influence on innovation adaptation for meeting market requirements and market entrance.

We also conclude from our research that enterprises working on research-driven innovation processes should include customers or other business partners early in their innovation process to meet market requirements. Enterprises working on market-driven innovation processes should develop relationships with universities as well to facilitate their research process. In market-driven innovation processes, enterprises especially benefitted from business partners and customers because they also raised the enterprises' attention to additional factors of the innovation environment such as institutional set-up and economic structure. Hence, an early indicator for innovation processes which can successfully enter a future market could be the interfirm relationships to customers.

Regarding the other areas of the conceptual framework, we only found minor infrastructural problems in the investigated enterprises, and no factors of the policy structure influenced the innovation processes. However, a lack of factors directly influencing innovation processes does not imply that the policy structure is unimportant for innovation. Most likely, the influence of the policy structure was more noticeable at the level of the entire enterprise, and not specifically associated with the specific innovation process.

Lastly, we observed a lack of public support especially during later stages of the innovation processes. Hence, it is crucial for enterprises to know who should be approached for information on foreign institutional set-ups and economic structures, especially when trying to enter a foreign market. We conclude that external actors are especially important for enterprises working in a cross-border region and cross-border cooperation can facilitate innovation processes.

While we believe our study has revealed important results, we are aware of its limitations. First, the explorative nature of our study based on qualitative interviews defines clear limits with regard to generalizing the results to other cases. Hence future research should investigate cross-border innovation in other geographical areas, industry sectors, for other types of innovation, or in larger enterprises. Research methods avoiding time-consuming face-to-face interviews might increase the subjects' willingness to participate in such research endeavours thereby increasing sample size. While we tried to acquire a regionally balanced sample of enterprises for our study, the fact that our sample largely consisted of enterprises participating in one specific Interreg project that hence were open to cross-border collaboration might have introduced some selection bias. Through adhering to research protocols and the coding tree while conducting and analysing the interviews we aimed to reduce researcher bias. Content-wise, additional research is necessary to

investigate how the support for enterprises working on innovation processes can be more targeted to their continuously changing needs related to research, relationships or funding – irrespective of whether innovation processes are driven by consumers, business partners or research. Furthermore, research should also focus on identifying factors that keep enterprises from using available instruments of financial support and cross-border cooperation in the EU.

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