Knowledge is only Power when it is Shared

A research on the effects of knowledge spillovers on firm's innovativeness

Radboud Universiteit

Femke van de Vondervoort

S1065947

Supervisor: Peter Vaessen

2nd examiner: Sjors Witjes

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Femke van de Vondervoort
S1065947
femke.vandevondervoort@ru.nl

Radboud University
Nijmegen School of Management
Nijmegen

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Thesis supervisor
Peter Vaessen
Peter.vaessen@ru.nl

Second examiner
Sjors Witjes
sjors.witjes@ru.nl

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Preface

Before you lies the thesis “Knowledge is only Power when it is Shared”. This title is a derivate of the expression ‘knowledge is power’, because I believe when you keep all your knowledge to yourself it will not provide you any power.

This piece was written to fulfil the graduation requirements of the Master programme Business Administration, specialization Strategic Management at the Radboud University, Nijmegen School of Management. This journey started 19 January 2022 with a kick-off meeting with my supervisor and fellow students.

Since then I have learned a lot, about doing research and writing a paper, but also about myself and how I deal with stress (not always ideally). So I am thankful that I have experienced this and will take all this new knowledge with me in my following journeys.

I would like to thank my supervisor, Peter Vaessen, for his support and guidance during this process. More than once I got stuck and he encouraged me to continue in good spirits by helping me practically and sharing his knowledge.

Furthermore, I would also like to thank Sema Topaloglu and Sharif Tah for their generous feedback provided during the thesis circles. It really helped me and made this research paper as it is now. My thanks furthermore go to professor Sjors Witjes for being my second examiner.

Lastly I would like to thank my parents, most of the time writing this piece, I was behind my desk for the whole day. But they accompanied me during my lunch and dinner breaks or brought me a fresh cup of tea so I could continue hydrated.

I hope you enjoy your reading.

Femke van de Vondervoort

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Abstract

Literature shows us that firms can innovate without performing R&D activities, although this research on non-R&D innovation is quite little. This study tries to unravel if knowledge spillovers have an effect on firm innovativeness, to fill this gap in literature. Knowledge spillovers are the appearance whereby investments in knowledge creation by one party produce external benefits by facilitating innovation by other parties. These knowledge spillovers could explain how more than half of the European firms that are innovative, do not conduct R&D, not internally nor externally. To investigate this, the following objective is composed: This study sets to examine in what respect external non-R&D collaborations generate knowledge spillovers affecting the different types of innovativeness of Dutch manufacturing firms.

To do so, this research includes literature study and empirical research. This latter consists of regression analyses to look at the linear relations between external non-R&D collaborations and the different innovation appearances and of mediation analyses. These are conducted to investigate the indirect effect of external non-R&D collaborations on technological product innovation, through R&D. The data that is used for this is derived from the European Manufacturing Survey and consists of 177 Dutch manufacturing firms.

The most important results these analyses yielded are that external non-R&D collaborations generate knowledge spillovers that affect non-technological innovations, but not technological innovations. For both organizational innovation and product-service innovation a significant and positive effect was found. The relations between external non-R&D collaborations and process innovation and product innovation were not found significant. The indirect relation through R&D was insignificant either.

The conclusion we can derive from this, is that external non-R&D collaborations only affect non-technological innovation. That it would not affect product innovation was taken into account, hence the indirect effect was measured. But that the indirect effect was not significant and that external non-R&D collaborations did not seem to have an effect on process innovation were unexpected.

Key words: knowledge spillovers, external non-R&D collaborations, innovativeness, non-R&D innovation

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1. Introduction

1.1 Introduction of the topic

This study will try to unravel if knowledge spillovers have an effect on different types of innovation of technological firms. It turns out that not all firms that are innovative, conduct R&D activities (Arundel et al., 2007; Huang et al., 2007). This implies that R&D is an important determinant for innovation, but that firms can also be innovative based on two other resources: 1. Employee-driven innovation (Fenwick, 2003; Høyrup, 2012) and 2. (external) knowledge spillover theory (Jaffe et al., 2000; Vernon Henderson, 2007). Knowledge spillovers are the phenomenon whereby investments in knowledge creation by one party produce external benefits by facilitating innovation by other parties, according to Jaffe et al. (2000). But knowledge spillovers is a term that knows various definitions and is hard to measure according to Krugman (1992): "knowledge flows, by contrast, are invisible; they leave no paper trail by which they may be measured and tracked". Therefore, knowledge spillovers get measured by a derivative variable.

Schumpeter is the founder of innovation thinking and he states that innovation has multiple appearances (Laskowska-Rutkowska, 2008). Armbruster et al. (2006) divided innovation into technological process innovation, technological product innovation, non-technological organizational innovation and non-technological product-service innovation.

Established literature on knowledge spillovers is in any quantity researched on the basis of data on patents (De Noni et al., 2018; Hollanders & ter Weel, 2002; Jaffe et al., 1993; Schmidt, 2006; Singh, 2005), but I believe that is a too narrow approach. Hence, this research will investigate the matter by looking at external non-R&D collaborations between firms and not only research the effects of knowledge spillovers on patentable concepts like process and product innovations, but also on organizational and product-service innovation.

1.2 Cause and relevance of the problem at hand

The main reason to investigate whether knowledge spillovers have an effect on the innovativeness of firms is because most of the literature that is present about innovation, is about R&D-driven innovation (Bogliacino & Vivarelli, 2012; Bronzini & Piselli, 2016; Mairesse & Mohnen, 2004). But if so much innovation is derived from R&D activities, then how is it possible that there are plenty of innovative firms which do not conduct or outsource R&D activities (Arundel et al., 2007; Huang et al., 2007)?

Hirsch-Kreinsen (2008) states that technological innovations not necessarily depend on R&D and Lopez-Rodriguez and Martinez-Lopez (2017) write that non-R&D innovation activities account for a significant portion of innovation efforts carried out across very heterogeneous economies in Europe. In Australia and Norway, the propensity to introduce a new-to-market product innovation is similar whether or not the firm performs R&D. This is referred to as hidden or neglected innovators (Hervas-Oliver et al., 2015). In fact, the third European Community Innovation Survey (CIS-3) shows that more than half of the European innovative firms did not conduct intramural or extramural R&D (Arundel et al., 2007; Huang et al., 2007). This means that organizations can conduct other activities besides R&D activities to be innovative.

Literature points out four main methods how organizations can be innovative without R&D: technology adoption, minor modifications or incremental changes to products and processes, imitation including reverse engineering and combining existing knowledge in new ways (Arundel et al., 2007). Technology adoption is the acquisition of innovative products, processes or ideas for organizational innovations from outside the firm, with little to no further work required. Minor modifications/ incremental changes can be made to acquired products and processes, as well as to in-house developed technologies. These modifications and changes are mostly made to the production process and depend on learning-by-doing. Imitation contains the activities to replicate an existing product or process, this often does not require R&D. Combining existing knowledge in new ways can contain some types of industrial design and engineering projects, but it can also include cases where organizations use solutions which are developed by users, also called user innovation (Arundel et al., 2007). The knowledge obtained for these methods can come from knowledge spillovers (Fritsch & Franke, 2004; Kim & Park, 2015).

Up until now, these knowledge spillovers are often researched on the basis of data on patents (De Noni et al., 2018; Hollanders & ter Weel, 2002; Jaffe et al., 1993; Schmidt, 2006; Singh, 2005). But because innovation knows various appearances, patents do not display the whole effect knowledge spillovers have. Firstly because by tracking patent citations, only codified knowledge is being investigated, while tacit knowledge could also play a significant role in knowledge spillovers and on innovation in clusters (Fallah et al., 2004). Secondly, looking at data on patents is too narrow because only products and processes can be patented, so the effect of knowledge spillovers on non-technological innovation is being left out up until now. This research assumes that the knowledge spilled over, also affects organizational

structures, business practices, workplace organization and offered services of the involved organizations. And thirdly, when only looking at patent citations you will miss a lot of implemented innovations that are based on such patents but which are not documented including citations referring to the original patent. On top of this, Tödtling and Grillitsch (2014) found proof that the knowledge sources different types of innovation rely on, differ. They researched process, organizational and market innovation. For this reason it would be interesting to investigate whether this is also the case for the different types of innovation this research contains, namely process innovation, product innovation, organizational innovation and product-service innovation, based on the Schumpeterian definition of innovation (Armbruster et al., 2008).

So therefore, it would be better to look at all different appearances of innovation in a firm, instead of only focussing on process and product innovation. To be able to see if indeed knowledge spillovers also have an effect on non-technological innovation this present research will analyse on micro-level if there is a relationship between knowledge spillovers and the different types of innovation appearances separately.

1.3 Problem framing in terms of academic literature

Existing literature about knowledge spillovers is quite contradicting. Hervas-Oliver et al. (2015) state that new-to-market product innovation is similar whether or not firms perform R&D. This would imply knowledge spillovers can also lead to radical product innovation. This while a lot of other literature analysed that non-R&D activities mostly lead to incremental product innovation (Fischer, 2006; Jirjahn & Kraft, 2011; Teece et al., 1994). Other state that the relationship between knowledge spillovers and (product)innovation is indirect, going via R&D (Audretsch & Feldman, 1996; Hervas-Oliver et al., 2011; Xie et al., 2019).

Although, the outcomes of knowledge spillovers are in principle unpredictable, according to Perri and Peruffo (2016): the acknowledgement that the movement of knowledge is unpredictable. Besides, the transfer of tacit knowledge does not follow standardized and formalized paths in an organization. Rather, it comes about through ad hoc, random, unpredictable, and reciprocal interactions between the knowledge sender and knowledge recipient and typically demands qualitative rather than quantitative changes to existing activities (Audretsch & Belitski, 2021; Sanchez & Heene, 1997). This could be the reason why Fritsch and Franke (2004) could answer the question of how spillovers come about. They concluded that R&D cooperation is a relatively unimportant medium for knowledge spillover,

but did not succeed in explaining how the majority of innovation-relevant knowledge spillover occurs within a region.

Vernon Henderson (2007) tells us that despite the fact that knowledge spillovers are central to notions of economic growth, technological progress, and the nature and characteristics of cities, research on the nature of such spillovers is surprisingly limited. While we have correlation and strong hints of more between agglomerations of quantifiable knowledge (such as patents) and productivity, we do not have "natural experiments" that would allow us to nail the causal connection and properly quantify benefits. Vernon Henderson (2007) states that this has to do with key impediments to inference, because there are a lot of missing variables and the selection is very hard.

The paper of Pittaway et al. (2004) states that there is evidence suggesting that network relationships with suppliers, customers and intermediaries are important factors affecting innovation performance and productivity. But it also recognizes several gaps in the literature that need to be filled. They write that further exploration is needed of the relationship between networking and different forms of innovation such as process and organizational innovation.

So literature pretty much tells us that knowledge spillovers are an important phenomenon, have an impact on the innovativeness of firms, but that literature still lacks, inter alia, on data about the effect of knowledge spillovers on different types of innovation.

1.4 Research objective and research question

Objective

This study sets to examine in what respect external non-R&D collaborations generate knowledge spillovers affecting the different types of innovativeness of Dutch manufacturing firms.

Research question

The following research question is formulated based on the research objective:

In which respect do external non-R&D collaborations generate knowledge spillovers affecting innovativeness in industrial companies?

Sub-questions

The following sub-questions are formulated to help answer the focal question:

- To what extent do external non-R&D collaborations generate knowledge spillovers affecting technological process innovation?
- To what extent do external non-R&D collaborations generate knowledge spillovers affecting technological product innovation?
- To what extent do external non-R&D collaborations generate knowledge spillovers indirectly affecting technological product innovation via R&D?
- To what extent do external non-R&D collaborations generate knowledge spillovers affecting non-technological organizational innovation?
- To what extent do external non-R&D collaborations generate knowledge spillovers affecting non-technological product-service innovation?

1.5 Outline of the thesis

Chapter 2 of this research paper will provide theoretical background of the most important concepts of the subject and shows the conceptual model of this master thesis. This chapter will be followed by chapter 3 which contains the methodology of this research. The research method, data sample, analysis procedure and limitations will all be explained. Chapter 4 will be dedicated to the empirical research including regression analyses and mediation analyses. Chapter 5 and 6 cover respectively the conclusion and discussion of this master thesis.

2. Theoretical framework

This chapter provides relevant literature about the dependent and independent variables, the hypotheses of this research and is being closed off with the conceptual model of this thesis. Because knowledge spillovers will be measured on the basis of external non-R&D collaborations, will they both be included in this chapter.

2.1 Descriptive theory

2.1.1 Dependent variable: innovation

OECD (2005) defines innovation as follows: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method, in-business practices, workplace organization or external relations". Within innovation there are three concepts of novelty: new to the firm, new to the market, and new to the world. The minimum requirement for an innovation is that the product, process or method must be new (or significantly improved) to the firm. So these can be products, processes and methods first develop, but also those that have been adopted from other organizations.

Some changes are not considered innovations: ceasing to use a process or marketing or organization method, or to market a product, simple capital replacement or extension, changes resulting purely from changes in factor prices, customisation, regular seasonal and other cyclical changes and trading of new or significantly improved products (OECD, 2005).

An *innovative firm* is one that has implemented an innovation during the period under review. Firms may have innovation activities in the reviewed period without having implemented an innovation. All activities involved in the development or implementation of innovation, including those planned, are innovation activities. Innovation activities can be of three kinds: successful (resulted in the implementation of an innovation), ongoing (work in progress) and abandoned (before the implementation of an innovation). An *innovation-active firm* is one that has had innovation activities of one or more of these three kinds during the period under review (OECD, 2005).

Based on the Schumpeterian definition of innovation he published in 1934 we can distinguish five different types of innovation: new products, new production methods, new markets, new sources of supply and new forms of organization. Researchers among Schumpeter claim that, innovation includes technical aspects (e.g. new products and new production methods), non-technical aspects (e.g. new markets and new forms of

organization), product innovations (e.g. new products or services) and process innovations (e.g. new production methods and new forms of organization). Based on this contemplation, four types of innovation can be distinguished: technical product innovation, technical process innovation, non-technical organizational innovations and, non-technical product-service innovation. (Armbruster et al., 2008; Armbruster et al., 2006; Laskowska-Rutkowska, 2008).

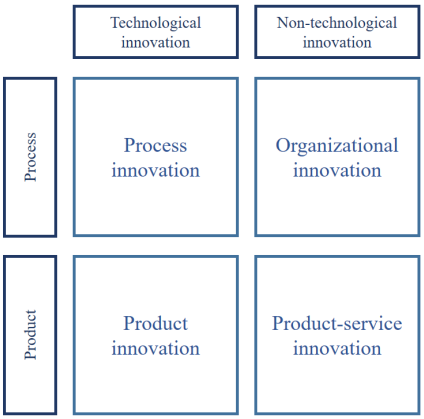


Figure 1: Four fields of innovation (Armbruster et al., 2006)

Process innovation is the implementation of a new or significantly improved production or delivery method (manufacturing process). This includes significant changes in technique, equipment and/ or software (OECD & Communities, 2005). With process innovation companies try to make their production process faster, cheaper, and with higher quality products (Laskowska-Rutkowska, 2008).

Product innovation is the introduction of a good, service or technology that is new or significantly improved with respect to its characteristics or intended used. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics (Laskowska-Rutkowska, 2008; OECD & Communities, 2005).

Organizational innovation is the development and implementation of a new organizational method in the firm's organizational structures, business practices, workplace organization or external relations (business process) (Laskowska-Rutkowska, 2008; OECD & Communities, 2005).

Product-service innovation means the delivery of a new service, with or without in combination with a physical product (e.g. maintenance) which should offer customers more flexibility and efficiency (Laskowska-Rutkowska, 2008).

2.1.2 Independent variable: knowledge spillovers

Literature provides a variety of different definitions for knowledge spillovers, such as:

Jaffe et al. (2000) say the following about knowledge spillovers: whereby investments in knowledge creation by one party produce external benefits by facilitating innovation by other parties.

Fallah et al. (2004) state that spillovers are the unintentional transmission of knowledge to others beyond the intended boundary. If knowledge is exchanged within the intended people or organization, it is "knowledge transfer", knowledge that is exchanged outside the intended boundary is spillover. The unintended "use" of exchanged knowledge is called knowledge externality.

Kim and Park (2015) refer to knowledge spillovers as knowledge diffusion from the creators of knowledge to other firms and agents, through which society will benefit.

According to Konno (2016) knowledge spillovers are "unintentional flows of knowledge from one network party to another" and differ from other types of knowledge transfer as there is no deliberate action to obtain the knowledge as it happens by chance. The spillover of knowledge has a significant effect on economic growth and the productivity of an individual firm. The spillover process among firms can be represented as a process on complex networks.

Innovation depends on the exchange of ideas among individuals, which economists call knowledge spillovers. A given company's innovation may stimulate a flood of related inventions and technical improvements by other companies (Carlino, 2001).

As can be seen, an important distinction can be made between scientists that claim knowledge spillovers only include tacit knowledge that is being exchanged unintendedly, and others write that it covers all knowledge a third party benefits of. Because this study wants to provide an answer to how firms without in-house or outsourced R&D department can be innovative, both tacit and codified knowledge, and intended as well as non-intended knowledge spillovers are taken into account.

Knowledge spillovers can be classified in different ways. Here different sorts, types and levels of knowledge spillovers will be discussed.

Knowledge spillover types

Literature distinguishes three theories about knowledge spillovers: MAR spillover, Porter spillover and Jacobs spillover (Van Stel & Nieuwenhuijsen, 2004).

The first theory about knowledge spillovers comes from Marshall, 1890; (Arrow, 1962) and Romer, 1986, also called MAR spillover. Their assumption is that knowledge spillovers are most effective between homogeneous companies. So spillovers mostly emerge within one sector. In this theory, regional sectoral growth is maximized if the sector is dominating the region and if the local competition is not too strong (Van Stel & Nieuwenhuijsen, 2004). Firms want to be as close to the sources of information as possible, because MAR spillover suggests that employees from different firms in an industry exchange ideas about new products and production processes. So the denser the concentration of employees in a certain sector in a given region, the greater the opportunity to exchange ideas that lead to key innovations (Carlino, 2001). Porter agrees with MAR that knowledge spillovers between firms in specialized sectors (sectors which are concentrated in certain regions) stimulate economic growth. But, unlike MAR, Porter assumes that local competition has a positive impact on growth. Because local competition in contrast to local monopoly fosters the pursuit and rapid adoption of innovation. This because it accelerates imitation and upgrades innovation. So although competition decreases the relative benefit for the innovator (larger spillovers flow to competitors), the amount of innovative activity will increase because the companies that do not innovate their products and production processes will not be able to compete with their competitors and ultimately go bankrupt (Van Stel & Nieuwenhuijsen, 2004). Porter spillovers are maximized in cities with geographically specialized, competitive industries (Glaeser et al., 1992). Jacobs breaks with these two theories by assuming that knowledge spillovers work out best among enterprises that practice different activities. So that knowledge spillovers are related to the diversity of industries in an area, instead of one common industry like in MAR an Porter spillovers. Meaning that inter-sectoral knowledge transfers would be most significant. Jacobs thus states that sectors grow the most in regions where various sectors are important, so regions with high diversity will thrive (Van Stel & Nieuwenhuijsen, 2004). Jacobs argues that industrially diverse regions encourages innovation because it encompasses people with varied backgrounds and interests, and so facilitating the exchange of ideas among individuals with different perspectives (Carlino, 2001). Jacobs agrees with Porter, that local competition stimulates economic growth (Van Stel & Nieuwenhuijsen, 2004).

Table 1 provides a summary of the three theories about knowledge spillovers:

	Competitive environment	Monopolistic environment
Technological cluster	Porter effects	MAR effects
Diversity of industries	Jacobs effects	-

Table 1: Classification of knowledge spillover effects by industry geographically concentration (Trachuk & Linder, 2019)

When looking at the theory of Jacobs, you could recognize something of the theory of Granovetter (1973) and Burt (2004) in there. Granovetter (1973) wrote about the strength of weak ties: when you are looking for new information, it is better to not consult your friends since they usually feature the same knowledge. The real valuable, innovative ideas come from a weak tie. This weak tie forms a bridge between two worlds. When applying this theory to the spillover theory it would mean that firms learn the most from firms that are not in the same sector as them, because those direct competitors will probably possess the same knowledge. Burt (2004) talks about structural holes in his book, wherein he states that the level of homogeneity of information, new ideas, opinions and behaviour is higher within groups than between groups, so people that are connected across different groups are more familiar with alternative ways of thinking and behaving. The bridge or 'broker' that mediates between these groups provides a vision of options that otherwise remain unseen, which allows him to come up with innovative ideas.

These theories fit in with Jacobs' theory, because she states that regions with diverse sectors, so weak ties or structural holes, encourage most innovation (Carlino, 2001). Therefore, the empirical part of this research will be done by means of Jacobs' knowledge spillover.

Levels of knowledge spillovers

Knowledge can be spilled over on different levels: on individual level between people, on enterprise level between firms and on global level between nations (Guerrero & Urbano, 2014). Knowledge spillovers on individual level consists of knowledge which is unintentionally exchanged between people. Knowledge exchanged between companies can happen with neighbouring companies, or when these firms are working together. Global level knowledge spillovers also happen between neighbouring countries or when nations trade with another (Fallah et al., 2004). This research focusses on enterprise level knowledge spillovers.

Direct and indirect knowledge spillovers

Knowledge can spillover in a direct manner, or in an indirect manner. Indirect knowledge spillovers come from the knowledge your partners have access to, but they did not produce. When the knowledge spilled over is produced by your partner itself, it is called a direct knowledge spillover (Fershtman & Gandal, 2011; Serrano-Domingo & Cabrer-Borrás, 2017).

A form of direct knowledge spillover would be if an university obtains knowledge about something and that gets spilled over to company A, where they are cooperating with. Indirect knowledge spillover would be the case here, if another company B, which is not directly linked to the university, benefits from that knowledge, because it gets spilled over from company A to them (P. Vaessen, personal communication, March 21, 2022). For this research, both direct and indirect knowledge spillovers are taken into account.

Intended and non-intended knowledge spillovers

Knowledge can be exchanged intendedly or not intendedly. A form of intended knowledge exchange is a patent. To get a patent firms need to explicitly describe what the product or process consists of and how it works, this knowledge can then be easily taken over by other companies (Fallah et al., 2004). Non-intended knowledge flows while firms do not want that to flow, like when employees take their knowledge and experience to another employer. This research will look into intended and non-intended knowledge spillovers.

Codified and tacit knowledge

Tacit knowledge is introduced by Michael Polanyi in 1958 and pointed to the existence of "the tacit dimension of knowledge", a form or component of human knowledge distinct from, but complementary to the knowledge explicit in conscious cognitive processes (Cowan et al., 1999). Codified knowledge, according to Cowan et al. (1999), is an obvious reference to codes, or to standards – whether of notation or of rules, either of which may be promulgated by authority or may acquire "authority" through frequency of usage and common consent, by de facto acceptance. Firms can access tacit knowledge by hiring experts and taking over other firms, and can be protected by long-term contracts with employees. Codified knowledge can be bought in the market and protected by patents and other forms of intellectual property rights. Tacit knowledge can be transformed into codified knowledge by codification processes (Johnson, 2002). But Johnson (2002) also states that the dichotomy between codifiable and non-codifiable knowledge is problematic since it is rare that a body of knowledge can be

completely transferred into codified form without losing some of its original characteristics and that most forms of relevant knowledge are mixed in these respects. Tacit and codified knowledge will both be taken into account in this study.

2.1.3 Derivative variable of knowledge spillovers: external non-R&D collaborations

As pointed out in the introduction, knowledge spillovers are hard to measure (Hollanders & ter Weel, 2002; Schmidt, 2006). Therefore, this research makes use of an alternative variable for knowledge spillovers, namely external non-R&D collaborations. Literature shows that this is a good deriviate variable for knowledge spillovers:

Fritsch and Franke (2004) indeed see that literature is trying to see if cooperative relationship between regional actors are an important vehicle for spillovers. So some authors argue that policy could contribute to a wider and faster diffusion of knowledge spillovers by actively stimulating cooperative relationships or at least by not hindering them, motivated e.g. by the desire to secure a competitive market structure.

Vernon Henderson (2007) increasingly thinks many spillovers are not accidential or the result of espionage, but rather the product of deliberate exchanges, as suggested by the wide literature on networking. He thinks of spillovers occuring in networks and information exchange as a largely non-market transaction.

Singh (2005) found evidence that interpersonal networks are quite important in determining patterns of intraregional and intrafirm knowledge flow, but their full impact might be hard to measure because collaborations on patents only represent a small portion of the overall set of social relations.

2.1.4 Mediating variable: research & development

Quite some articles in literature state that product innovation can only be achieved by R&D activities. Their results show that for product innovation the relationship goes from knowledge spillovers via R&D to product innovation (Audretsch & Feldman, 1996; Hervas-Oliver et al., 2011; Xie et al., 2019). Others state that with non-R&D innovation only incremental changes can be achieved, no radical innovations (Fischer, 2006; Jirjahn & Kraft, 2011; Teece et al., 1994). To check if it is true that product innovation can hardly be achieved without R&D activities, both the direct relationship between knowledge spillovers and product innovation as well as the indirect relationship of knowledge spillovers on product innovation via R&D will be tested.

The OECD defines R&D as follows: “Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.” (OECD, 2002). The term R&D covers three activities: basic research, applied research and experimental development.

Some activities do not belong to R&D: education and training, other related scientific and technological activities (e.g. collecting, coding, translating and evaluating), other industrial activities (e.g. acquisition of technology, industrial engineering and design) and administration and other supporting activities (e.g. purely R&D-financing activities and indirect supporting activities) (OECD, 2002).

R&D activities can be conducted in two ways: in-house or outsourced. Solely relying on in-house R&D has become unsatisfactory because of the growing complexity and speed of technological developments. But both of the two types are controversial. Common knowledge tells use due to economies of specialization and knowledge spillovers, outsources R&D obtains bigger productivity gain. Also, outsourced R&D stimulus spillovers from the outside to the firm’s absorption capacity, and thus improve a firm’s innovation capabilities. But in contrast to this, other authors claim that in-house R&D is better in terms of productivity. This because of the firm’s absorption capacity and because of the transaction costs incurred in setting up and managing the collaborative agreements which may impede the outsourced R&D, and lastly because of the costs of collaborative activities that cancel out positive impacts of innovation collaboration in the short term, leading to a negative effect on firm profitability (Ngo, 2020). In this research, both in-house and outsourced R&D are taken into account.

2.2 Explanatory theories

Knowledge spillovers emerge when an investment in knowledge creation by one party produces external benefits by facilitating innovation by other parties (Jaffe et al., 2000). Sources of this knowledge are publications, patents, human capital and research institutions (Ghio et al., 2015).

The information sources for knowledge spillovers are usually located in public domains and depend on a firm’s ability to create information flows from the public pool of knowledge, such as patents, publications, and technical and industrial associations (Audretsch et al., 2021). Because the source is often located in public domain, the technical property of

knowledge is generally non-excludable: whoever may use a knowledge spillover has generally no incentive to compensate the producer of this externality for his or her beneficial activities (Döring & Schnellenbach, 2006), but Yang et al. (2010) and Yang and Steensma (2014) state that also the originating firm can benefit from knowledge spillovers. They can achieve this by benefitting from the innovations the recipient firms implemented based on the knowledge the originating firm spilled over. This is called a spillover knowledge pool.

Another way knowledge spillovers emerge is because employees switch jobs and take their knowledge with them to their new employer (Agarwal et al., 2009), or when employees leave the firm to start a business for their own with the knowledge they gained when they were under contract at that originating firm (Ghio et al., 2015).

Universities also play a role within knowledge spillovers. University activities involve formal and informal interactions and their research output is considered a knowledge spillover source, including through its role in creating start-ups and their spin-offs (Davies et al., 2021).

Relationship between knowledge spillovers and

… Technological process innovation

The European Union has a fundamental target that the rate of R&D investments should be 3% of GDP, the study by Hervas-Oliver et al. (2011) however stated that SMEs innovation relies on a variety of internal (both R&D and non-R&D) and external drivers, such as collaboration with other firms and research centres and is profoundly influenced by location and context. So they argue place-blind increases in R&D investments may not deliver the best outcomes. This paper showed us that non-R&D activities are important drivers for process innovation. Internal HR and internal suppliers, and external sources of knowledge are both critical. This study contained 2023 available firms from a body of the Spanish Ministry of Industry, with data from the years 2005 and 2006. The objective of the study was threefold: to understand what role non-R&D input activities play to explain a firm's innovative process and product performance, tackle the role of the non-R&D innovations and their strategies combining internal and external resources to innovate, and lastly: exploring the process of innovation disentangling the ambiguous results of the literature about the effects of absorptive capacity to access external sources of knowledge and the medation effect of combining internal and external sources of knowledge. Similar results were found in Klevorick et al. (1995), Lee et al. (2001) and Hervás-Oliver et al. (2021). This leads to the following hypothesis to be tested:

Hypothesis 1: The greater the number of external non-R&D collaborations, the stronger their impact upon technological process innovation.

… Technological product innovation

Lasagni (2012) wrote that the word 'innovation' was originally linked to the role of R&D, but currently, it is more associated with the knowledge used in the process of generating new ideas. Therefore, he dove into the idea that innovation results are favoured by the presence of relationships, networks, alliances and other forms of interaction with external sources of knowledge. To do so, he addressed two principal research questions: are SMEs that are proactive in strengthening their relationships with innovative suppliers and customers more likely to achieve positive results in the innovation of products or services? And second: Are innovative SMEs more likely than other SMEs to take advantage of linkages with R&D laboratories and universities? Data to answer these questions was collected using a survey of managers working in approximately 600 SMEs in six different European countries (Austria, Germany, Hungary, Italy, Poland and Slovenia). Innovation performance was measured with two variables: range innovativeness and turnover from new products. Lasagni (2012) concluded that SMEs which are proactive in strengthening their relationships with innovative suppliers, users and customers have a higher innovation performance. Moreover, firms will have better new product development results if they improve their relationships with laboratories and research institutes. Based on this research the second hypothesis can be outlined as follows:

Hypothesis 2a: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation.

Xie et al. (2019) did research to see if non-R&D innovation has an effect on new product performance. To find these results they used 200 valid questionnaires, sent out to senior managers and R&D managers of manufacturing firms located in the Yangtze Delta Region in China. New product performance was measured using six 5-point Likert scale items, for the independent variable non-R&D innovation they used a four-dimensional construct, where each dimension was measured using three items. For the moderating variable R&D intensity, they conceptualized the annual R&D expenditure of a firm divided by total sales. The relationship between the independent and dependent variable turned out to be significant and positive. They further found out that the interaction term between non-R&D innovation and R&D intensity was positive and significant for new product performance. As read above,

Hervas-Oliver et al. (2011) found that non-R&D activities important drivers are for process innovation, but that product innovation can only be explained on the basis of R&D activities. This would mean that product innovation can only be achieved when the non-R&D activities are combined with R&D activities. Similar results were found in Audretsch and Feldman (1996), consequently, the next hypothesis reads like this:

Hypothesis 2b: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation via R&D.

… Non-technological organizational innovation

Pittaway et al. (2004) wrote that there is a gap in literature about the relationship between networking and different forms of innovation, like process innovation and organizational innovation because the focus is mostly on product innovation. Radicic et al. (2019) tried to fill this gap by investigating if cooperation with suppliers, private sector institutions and public sector institutions increase the probability of introducing organizational innovation, and found that this is the case. They investigated this because there are plenty of benefits of cooperation on firms' innovation activities like risk pooling, cost sharing, shortening of the innovation process, fast commercialization of products, obtaining access to complementary and/ or similar resources, and access to external knowledge (Radicic et al., 2019). The sample included 312 SMEs from seven EU regions (in France, Germany, Italy, Netherlands, Portugal, Spain and, UK) noted for concentrations of traditional manufacturing industry. Their research question was: is there a non-linear (inverted U-shaped) relationship between the breath of cooperation and innovation performance? Therefore, the third hypothesis is formulated as:

Hypothesis 3: The greater the number of external non-R&D collaborations, the stronger their impact upon non-technological organizational innovation.

… Non-technological product-service innovation

For product-service innovation it is harder to find indications that external non-R&D collaborations have an impact on this dependent variable since little to no research has been conducted to this subject. But based on the fact that there are plenty of clues and theories that external non-R&D collaborations have an effect on technological product innovation and on non-technological process innovation, the last hypothesis is as follows:

Hypothesis 4: The greater the number of external non-R&D collaborations, the stronger their impact upon non-technological product-service innovation.

2.3 Conceptual model

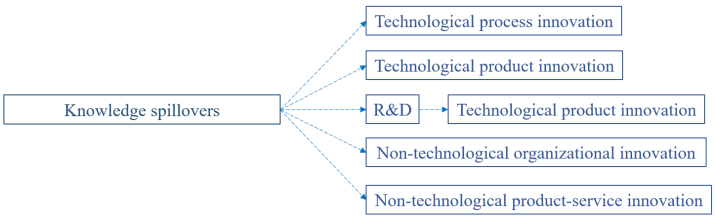


Figure 2: Conceptual model of the research

3. Methodology

This chapter explains the methodology that will be used to gather, analyse and interpret the necessary data for the research. It will also provide the operationalizing table and say something about research ethics.

3.1 Used sample, data source and taken measures

The population of this research is Dutch manufacturing companies. The sample that will be investigated for this research comes from the EMS (European Manufacturing Survey) (appendix 1). This secondary dataset contains valid data from 177 Dutch manufacturing firms. Measures that were being taken to optimize the internal validity of the survey are: detailed questions, trial surveys, international meetings with representatives from fifteen different countries with intensive discussions about the formulation of the question and the drafting of the questionnaire, and the questionnaires are being translated from English to Dutch and checked on translations. For the external validity, the following measures were taken: offering a free benchmark report where companies can compare themselves with other firms and lastly, sending out two reminders. This was done to obtain as much respondents as possible. Measures for the reliability of the survey are asking for experiences, not opinion questions, but asking for objective data: practices, facts, investments, and performance scores.

3.2 Intended analysis procedure

For this research, quantitative research will be conducted. The analysis of the data will be done using SPSS software. External non-R&D collaborations will be used as the independent variable and is tested by asking which types of external non-R&D collaborations the firm participates in. For the dependent variables goes: process, organizational and product-service innovation will be tested by adding up all the implemented innovations belonging to that innovation type. For product innovation the percentage of turnover of new offered products since 2012 will be used. As mediator the percentage of internal R&D employees will be used and for external R&D the number of R&D collaborations will be counted. All these variables are of metric measurement level.

To see if the hypotheses of the direct effects are supported, so the more external non-R&D collaborations, the stronger their impact upon the different types of innovation, regression analysis will be conducted. Because this technique can only handle one dependent variable at a time, the analysis will be performed four times. The basic equation of a regression analysis is as follows (Hair, 2019): $Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i$

With:

Y_i= dependent variable

β_0= population Y intercept (constant)

β_1= population slope coefficient

X_i= independent variable

ε_i= random error term

A few model assumptions have to be checked before being able to conduct the regression analysis. These assumptions are that the variables have to be of at least interval measurement level, the variables have to be normally distributed, the relation between predictor and dependent variable has to be linear, the level of multicollinearity may not be too high and the variance of all residuals at each level of the predictor variable has to be homoscedastic (Hair, 2019).

The indirect effect will be tested with two mediation analyses. This will be conducted using PROCESS v4.1 by Andrew F. Hayes in SPSS. The mediation analysis looks like this:

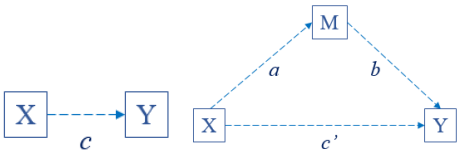


Figure 3: Conceptual model of a mediation analysis

Because Jacobs' does not claim knowledge spillovers only happen in close proximities like Porter (Van Stel & Nieuwenhuijsen, 2004), external non-R&D collaborations over all distances will be used. Besides, Jacobs states that knowledge spillovers happen mostly between firms that are active in different types of industries (Carlino, 2001), so all the external non-R&D collaborations are taken into account, not only the ones that exist within a certain sector. To avoid that the results are biased by the size or industry of the firm, these variables will be included in the regression model as control variables.

3.3 Operationalization table

Variable type	Name variable	Item	Min	Max	Measurement level	Remarks
DEPENDENT	Process innovation	8.1Which of the following technologies is currently applied in y	0	23	Interval	
		8.2Which of the following does your firm do to reduce energy	0	3		
	Product innovation	9.1b What share of turnover did the since 2012 introduced pro	0	100	Interval	In %
	Organizational innovation	3 Which of the following organizational concepts and working	0	18	Interval	
	Product-service innovation	10.1 Which of the following product related services do you o	0	8	Interval	
INDEPENDENT	External non-R&D collaborations	6.1 Does your business location cooperate with other companies	0	4	Interval	
MEDIATING	Cooperation in R&D	6.1 Cooperation in R&D with customers and suppliers	0	2	Interval	
CONTROL	Firm size	21 Firm size	10	1.000.000	Interval	
	Type of industry	1.2 Industry	0	1	Nominal	

Table 2: Operationalization table

3.4 Research ethics

Regarding research ethics, the researcher will conduct the complete research according to the principles (virtues) of the Dutch code of conduct for scientific integrity. This contains five principles: honesty (not doing unfounded claims), diligence (using scientific methods and optimal precision), transparency (being open about the used data), independency (not being led by non-scientific considerations) and responsibility (doing scientifically or social relevant research)(NWO, n.d.).

4. Empirical research

This chapter consists of the response data, variable construction, the univariate, bivariate and multivariate analyses and their fit to the hypotheses.

4.1 Response data

In total, the dataset consists of 177 respondents, two respondents include some missing data, so these are eliminated. This brings the amount of valid respondents to 175 (N = 175). Tables 3 and 4 show that the data consists of firms with different sizes and that are present in seven different sectors, namely: metal, food, textile, construction, chemical, machinery and electronic.

Firm size	Frequency	Percentage
Less than 20 employees	37	21,1%
20 to 49 employees	72	41,1%
50 to 99 employees	43	24,6%
100 to 249 employees	19	10,9%
250 or more employees	4	2,3%
Total	175	100%

Table 3: Sizes of the questioned firms

Type of industry	Frequency	Percentage
Metal	37	21,1%
Food	18	10,3%
Textile	22	12,6%
Construction	13	7,4%
Chemical	22	12,6%
Machinery	31	17,7%
Electronic	32	18,3%
Total	175	100%

Table 4: Industries of the questioned firms

4.2 Variable construction

Here, the variables that will be used to answer the focal questions will be explained.

4.2.1 Construction dependent variables

Process innovation

Process innovation is tested by two questions in the questionnaire: 8.1 'which of the following technologies is currently applied in your firm?' and 8.2 'which of the following does your firm do to reduce energy consumption?'. The first question consists of 23 items and the second question of three items. Because the variable 'process innovation' is tested by multiple measurements, we need to do an assessment of the degree of consistency between those measurements. By this, we test for reliability. A type of diagnostic measure is the reliability coefficient, this assesses the consistency of the entire scale, most of the times done using Cronbach's alpha. Cronbach's alpha should have a value of at least .70 (Hair, 2019). Here, the value of Cronbach's alpha is .768 (see appendix 2) so it meets the requirement of being higher than .70. This value cannot be increased since deleting items here would only lead to a lower value (see Cronbach's alpha if item deleted). Now we know that we can use these 26 items as one variable for process innovation. So, the more technologies a firm applied, the more process innovative the firm is. Mean here is 5,8, which is quite low considering firms could score up to 26 on this variable. The minimum score is zero and the maximum is 22 as can be seen in table 5.

	Frequency	Percent	Valid percent	Cumulative percent
,00	4	2,3	2,3	2,3
1,00	14	8,0	8,0	10,3
2,00	18	10,3	10,3	20,6
3,00	17	9,7	9,7	30,3
4,00	25	14,3	14,3	44,6
5,00	21	12,0	12,0	56,6
6,00	12	6,9	6,9	63,4
7,00	17	9,7	9,7	73,1
8,00	9	5,1	5,1	78,3
9,00	9	5,1	5,1	83,4
10,00	6	3,4	3,4	86,9
11,00	9	5,1	5,1	92,0

12,00	4	2,3	2,3	94,3
13,00	4	2,3	2,3	96,6
14,00	3	1,7	1,7	98,3
17,00	1	0,6	0,6	98,9
18,00	1	0,6	0,6	99,4
22,00	1	0,6	0,6	100,00
Mean	5,7600			
Total	175	100,00	100,00	

Table 5: Frequencies of the number of applied process innovations per business location

Product innovation

For product innovation, question 9.1b was used 'what share of turnover did the since 2012 introduced products that were new to the firm or technically drastically renewed have in 2014?'. Because this question does not consist of multiple items, the scale analysis is not needed. Table 6 includes an overview of the share of turnover in percentages. Mean of this variable is 13,8 with a minimum score of zero and a maximum of 90. There are 68 missing scores for this variable because that is the amount of firms that did not introduce any new products.

	Frequency	Percent	Valid percent	Cumulative percent
,00	6	3,4	5,6	5,6
1,00	7	4,0	6,5	12,1
2,00	7	4,0	6,5	18,7
3,00	2	1,1	1,9	20,6
5,00	18	10,3	16,8	37,4
8,00	1	,6	,9	38,3
10,00	21	12,0	19,6	57,9
12,00	2	1,1	1,9	59,8
15,00	13	7,4	12,1	72,0
17,00	1	,6	,9	72,9
20,00	12	6,9	11,2	84,1
25,00	6	3,4	5,6	89,7
30,00	5	2,9	4,7	94,4
40,00	2	1,1	1,9	96,3

45,00	1	,6	,9	97,2
70,00	1	,6	,9	98,1
80,00	1	,6	,9	99,1
90,00	1	,6	,9	100,00
Mean	13,7944			
Total	107	61,1	100,00	
Missing system	68	38,9		
Total	175	100,00	100,00	

Table 6: Frequencies of the percentage of turnover new products have

Organizational innovation

Eighteen items represent the organizational innovativeness of the questioned firms. The question to test for this is 3 'which of the following organizational concepts and working methods are currently applied in your firm?'. To assess the degree of consistency, Cronbach's alpha is measured and turned out to be .801, which is above the requirement of .70. This value could not be further increased by deleting items, see appendix 2. Mean here is 8,0, so it is almost in the middle and the minimum and maximum score match with the minimum and maximum possible: representatively zero and eighteen, as can be seen in table 7.

	Frequency	Percent	Valid percent	Cumulative percent
,00	2	1,1	1,1	1,1
1,00	7	4,0	4,0	5,1
2,00	5	2,9	2,9	8,0
3,00	11	6,3	6,3	14,3
4,00	8	4,6	4,6	18,9
5,00	12	6,9	6,9	25,7
6,00	17	9,7	9,7	35,4
7,00	17	9,7	9,7	45,1
8,00	18	10,3	10,3	55,4
9,00	17	9,7	9,7	65,1
10,00	12	6,9	6,9	72,0
11,00	14	8,0	8,0	80,0
12,00	13	7,4	7,4	87,4
13,00	7	4,0	4,0	91,4

14,00	6	3,4	3,4	94,9
15,00	4	2,3	2,3	97,1
16,00	4	2,3	2,3	99,4
18,00	1	,6	,6	100,0
Mean	8,0400			
Total	175	100,00	100,00	

Table 7: Frequencies of the number of applied organizational innovations per business location

Product-service innovation

For product-service innovation, a question was asked about which of the following product related services the business locations offer to their customers (10.1). This variable consists of eight items. For this question the Cronbach's alpha has a value of .772. This value cannot be increased by at least .05 so no items will be deleted (Field, 2018), see appendix 2. Table 8 presents an overview of how many firms offer a certain amount of product-services, with a minimum of zero offered services, a maximum of eight, and a mean of 2,8.

	Frequency	Percent	Valid percent	Cumulative percent
,00	34	19,4	19,4	14,9
1,00	22	12,6	12,6	32,0
2,00	31	17,7	17,7	49,7
3,00	29	16,6	16,6	66,3
4,00	17	9,7	9,7	76,0
5,00	16	9,1	9,1	85,1
6,00	11	6,3	6,3	91,4
7,00	7	4,0	4,0	95,4
8,00	8	4,6	4,6	100,0
Mean	2,8457			
Total	175	100,00	100,00	

Table 8:Frequencies of the number of offered product-services per business location

4.2.2 Construction independent variable

The independent variable in this research is external non-R&D collaborations. For this, question 6.1 'does your business location cooperate with other companies in the following areas?' is used. To measure this, four items are used, because the other two items contain R&D, which will be measured separately. The Cronbach's alpha here has a value of .618.

This is not very high, but cannot be heightened by deleting an item. Here the minimum score of external non-R&D collaborations is zero and the maximum is four, with a mean of 1,5 as shown in table 9.

	Frequency	Percent	Valid percent	Cumulative percent
,00	55	31,4	31,4	31,4
1,00	39	22,3	22,3	53,7
2,00	35	20,0	20,0	73,7
3,00	32	18,3	18,3	92,0
4,00	14	8,0	8,0	100,0
Mean	1,4914			
Total	175	100,00	100,00	

Table 9: Frequencies of the number of external non-R&D collaborations per business location

4.2.3 Construction mediating variable

For the indirect effect, two variables will be used. The first variable is about internal R&D: 15.2 'how many percent of the personnel is in the area of R&D?'. The minimum score here is zero and the maximum is 25, with a mean of 5,5. The second variable tests if the business location cooperates in R&D with customers and suppliers (6.1) and / or with research institutions (6.1). The Cronbach's alpha value for this variable is .502 and cannot be increased since it only consist of two items. The minimum score of this variable is zero and the maximum is two and has a mean of 0,9. Tables 10 and 11 show the frequency distribution of both variables.

	Frequency	Percent	Valid percent	Cumulative percent
,00	43	24,6	24,6	24,6
1,00	11	6,3	6,3	30,9
2,00	14	8,0	8,0	38,9
2,50	3	1,7	1,7	40,6
3,00	6	3,4	3,4	44,0
4,00	6	3,4	3,4	47,7
5,00	39	22,3	22,3	69,7
6,00	1	,6	,6	70,3
8,00	3	1,7	1,7	72,0
9,00	1	,6	,6	72,6

10,00	28	16,0	16,0	88,6
12,00	1	,6	,6	89,
15,00	7	4,0	4,0	93,1
20,00	11	6,3	6,3	99,4
25,00	1	,6	,6	100,0
Mean	5,5114			
Total	175	100,00	100,00	

Table 10: Frequencies of the percentage R&D personnel per business location

	Frequency	Percent	Valid percent	Cumulative percent
,00	64	36,6	36,6	36,6
1,00	61	34,9	34,9	71,4
2,00	50	28,6	28,6	100,0
Mean	0,9200			
Total	175	100,00	100,00	

Table 11: Frequencies of the number of external R&D collaborations per business location

4.2.4 Construction control variables

Two variables are included as control variables to enhance the internal validity. ‘type of industry’ and ‘firm size’ could influence the outcomes so these variables will be controlled for in the regression analysis (Bhandari, 2021). The frequency distributions of both variables can be found in table 3 and 4.

4.3 Univariate analysis

Table 12 provides an overview of the univariate analysis, including the mean, median, standard deviation, skewness, kurtosis and the minimum and maximum scores of all variables. As can be seen, all values of skewness and kurtosis are smaller than |1,96| (with $p < 0,05$) except for 'product innovation'. Although the bell shape is not a requirement for regression analysis, a non-symmetric distribution could have effects on the linearity and homoscedasticity, so it is better to meet this assumption (Field, 2018). With the exceedance of this rule by the variable 'product innovation' will be dealt in the next paragraph.

	External non-R&D collaborations	Process innovations	Product innovation	Organizational innovations	Product-service innovation	External R&D collaborations	Internal R&D	Industry	Firm size
N valid	175	175	107	175	175	175	175	175	175
Mean	1,4914	5,7600	13,7944	8,0400	2,8457	,9200	5,5114	4,0629	2,3200
Median	1,0000	5,0000	10,0000	8,0000	3,0000	1,0000	5,0000	4,0000	2,0000
Std. dev.	1,3169	3,8312	14,8843	3,8572	2,2905	0,8054	5,7476	2,2236	1,0002
Skewness	,378	1,051	2,774	,074	,575	,147	-1,247	-,102	,541
SE of S	,184	,184	,234	,184	,184	,184	,184	,184	,184
Kurtosis	-1,080	1,511	10,327	-,517	-,524	-1,443	-1,014	-1,484	-,200
SE of K	,365	,365	,463	,365	,365	,365	,365	,365	,365
Minimum	,00	,00	,00	,00	,00	,00	,00	1,00	1,00
Maximum	4,00	22,00	90,00	18,00	8,00	2,00	25,00	7,00	5,00

With: Std. dev.: Standard deviation, SE of S: Standard error of skewness and SE of K: Standard error of kurtosis

Table 12: Overview of the univariate analysis

4.4 Bivariate analysis

4.4.1 Multicollinearity

Any time a variate has two or more variables there is the potential for multicollinearity, the degree of correlation among the variables in the variate that may result in a confounding effect in the interpretation of the individual variables of the variate. So put in other words, the extent to which a variable can be explained by the other variables in the analysis (Hair, 2019). The used threshold for this is ($r > 0,9$). As can be seen in appendix 3, there are no values of Pearson Correlation higher than 0,9, so there is no question of multicollinearity in the data.

4.4.2 Expected relationships

By looking at the bivariate analysis table (appendix 3) we can also check for first indications of validity of the hypotheses.

First thing to notice is that all of the Pearson Correlations are positive, except for the one between internal R&D and type of industry. Besides, non-R&D external collaborations has a positive and significant effect on process innovation ($r = 0,241$, $p = 0,001$), organizational innovation ($r = 0,302$, $p < 0,001$) and product-service innovation ($r = 0,267$, $p < 0,001$). For product innovation the correlation is positive, but not significant. The correlations between internal R&D and product innovation and between R&D collaborations and product innovation are positive but not significant.

4.5 Multivariate analysis

4.5.1 Assumptions

Metric measurement level

One assumption that needs to be met for regression analysis is that all the variables have to be of interval or ratio measurement level. This is the case for all of the variables, except for the one on the industry the firms are in. For this variable six dummy variables have been created, with metal as their reference group.

Normality

In appendix 4, the P-P plots and histograms are shown to test for normality.

As can be seen from the histogram of process innovation, it looks a bit positively skewed and leptokurtic, but when looking at their values from the univariate analysis, the values of the skewness (1,051) and kurtosis (1,511) fall within the border of |1,96|, so we can assume process innovation is normally distributed. Looking at the histogram of product

innovation also gives an indication that the distribution is positively skewed and leptokurtic. Considering their values respectively on both measures: 2,774 and 10,327, we can state that for product innovation that is indeed the case. To solve this exceedance two types of transformations have been conducted: a log transformation (see appendix 5) and a square root transformation (see appendix 6). The first one seemed to have the most effect, and made sure now the values of the skewness (-,463) and kurtosis (-,070) fall within the set borders. For organizational innovation the histogram almost perfectly matches the normally distribution line. Product-service innovation seems a bit positively skewed, but the skewness value is only ,575, so that is nicely within the limits. These skews in process, product and product-service innovation are also visible in the P-P plots, since you can see a (little) S-shape of the dots, which implies skewness (Field, 2018).

Homoscedasticity

This assumption means that the variance of the outcome variable should be stable at all levels of the predictor variable. To test for this, we can look at Levene's test and at the residual plot (Field, 2018). Levene's test in appendix 7 show that none of the values are significant, which implies that all the variances in the groups are equal, so there is homoscedasticity.

Besides the Levene's test, also a residual plot is created for all the dependent variables. These are presented in appendix 8 and neither show a graph that funnels out (Field, 2018), so there is no heteroscedasticity.

Independence

This assumption means that the errors in a model are not related to each other. To check for this, the Durbin-Watson test can be used, which is a test statistic varying between zero and four. A value of two means the errors are uncorrelated, a rule of thumb here is that values lower than one or above three are cause for concern (Field, 2018). Here the values of process, product, organizational and product-service innovation are respectively 1,897, 1,917, 2,165 and 2,173, as shown in appendix 9. As can be seen these values all lay close to two, so independence of errors can be assumed.

Linearity

This assumption can also be tested with the residual plot, like homoscedasticity. If a curve is present in the graph, then the assumption of linearity cannot be assured (Field, 2018). But as can be seen in appendix 8 all the dots are randomly spread, so there is a linear relationship.

4.5.2 Overall fit of the model

Firstly we will look into the model as a whole, before diving into the separate variables. To do this, will take a look at the *F*-values because this tells the goodness of fit (Field, 2018). We can derive from table 13 that only for product innovation the *F*-value is not significant (p = 0,074), but for the other three innovation types it is. For the latter three goes that the *F*-value has a significance value of $p < 0{,}001$, so we may look at those three models.

Because there is only one predictor in all models, the R-value is the correlation between external non-R&D collaborations and the different types of innovation (Field, 2018). The R-values in the models are: 0,561 for process innovation, 0,364 for product innovation, 0,564 for organizational innovation and 0,552 for product-service innovation.

The value of R^2 tells us how much of the variation can be accounted to external non-R&D collaborations, and how much of the variation remains unaccounted for: other variables that have influence. The R^2 values of process innovation, product innovation, organizational innovation and product-service innovation are respectively 0,315, 0,132, 0,318 and 0,305. This means that for the innovation types respectively 68,5%, 86,8%, 68,2% and 69,5% of the variation remains unaccounted for. Looking at the adjusted R^2's of the model, Field (2018) uses three levels of explanatory power: 0.01 = low, 0.09 = medium and 0.25 = high. The models for process innovation, organizational innovation and product-service innovation have a high explanatory power.

Lastly, we have the B-value given for all the variables, this represents the change in the outcome associated with a unit change in the predictor. So for organizational innovation we can say that if a firm has one extra external non-R&D collaboration, the model predicts the firm will implement 0,562 extra organizational innovations. For product-service innovation is value is 0,317 and both are significant with $p < 0{,}05$. The B-values of external non-R&D collaborations in the process innovation and in the product innovation model are not significant.

	Dependent variables B (SE)			
	Process innovation	Product innovation	Organizational innovation	Product-service innovation
Independent variable				
External non-R&D collaborations	0,336 (,199)	0,070 (,033)*	0,562 (,200)*	0,317 (,120)*
Control variables				
Food	-0,656 (,485)	-0,259 (156)	1,681 (,941)	-1,402 (,564)*
Textile	-0,834 (,345)	-0,009 (157)	1,595 (,884)	-0,916 (,530)
Construction	-0,081 (,939)	-0,042 (,179)	-0,043 (1,070)	0,080 (,642)
Chemical	-1,000 (,258)	-0,218 (146)	1,697 (,885)	0,045 (,531)
Machinery	0,392 (,632)	-0,063 (,135)	0,533 (,820)	2,255 (,492)**
Electronics	0,657 (,403)	-0,315 (,138)*	1,068 (,788)	0,709 (,472)
Firm size	1,944 (,000)**	-0,030 (,042)	1,740 (,258)**	0,136 (,155)
Model information				
F-value	9,539**	1,868	9,694**	9,108**
R	0,561	0,364	0,564	0,552
R^2	0,315	0,132	0,318	0,305
Adjusted R^2	0,282	0,061	0,286	0,272
N	175	175	175	175
With: * $p < 0,05$ and ** $p < 0,01$				

Table 13: Outcomes of the regression analyses

Because the types of industry are all dummy variables, it is not possible to say anything about their B-value. To solve this problem, they are put back together as one by making a compound variable. For all four models, this provided a unstandardized coefficients B-value of 1,000 for industry type, while the other independent variables (external non-R&D collaborations and firm size) remain the same value. Because of this and because all four compound variables for the four models are significant with $p < 0,05$, we may look at the standardized coefficients Beta-value. Here we can see the strength of the effect with respect to the other independent variables. For process and organizational innovation, firm size has the largest Beta-value, respectively 0,508 and 0,541 and for product and product-service innovation industry type has the strongest effect, with respectively 0,281 and 0,484.

4.5.3 Fit with composed hypotheses

The first hypothesis, **H1**:the greater the number of external non-R&D collaborations, the stronger their impact upon technological process innovation, cannot be accepted. As seen in table 13, the model as a whole is significant (*F*-value of 9,539 with p <0,001), but the relationship between external non-R&D collaborations and process innovation is not significant (B-value of 0,336 with p = 0,093). This hypothesis was drawn up because Hervas-Oliver et al. (2011) found proof for this relation by investigating 2023 Spanish industrial firms, and similar results were found by other authors. A reason that this result deviates from Hervas-Oliver's outcome could be that he took into account all kinds of non-R&D activities, so internal HR and internal suppliers, as well as external sources of knowledge.

The second hypothesis, **H2a**: the greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation, can also not be accepted. This because the model as a whole is not significant (*F*-value of 1,868 with p = 0,074). The relationship between external non-R&D collaborations and product innovation is on the other hand significant (B-value of 0,070 with p = 0,036) but we may not interpret the model parameters when the overall fit of the model is not significant (Field, 2018). This model not being significant is contradictory to the piece of Lasagni (2012). He found that SMEs that proactively strengthen their relationships with innovative suppliers, users and customers have a higher range innovativeness and higher turnover from new products. It could be that his results were significant because he also looked at relationships with users and customers, while these groups were not present in this research because they do not belong to enterprise level knowledge spillovers. But the rejection of this hypothesis is on the other hand not a total surprise. As can be read in paragraph 2.1.4, there are clues in literature that product innovation cannot be achieved without R&D. For this reason, the effect of external non-R&D collaborations on product innovation via R&D will also be tested.

The third hypothesis, **H3**: the greater the number of external non-R&D collaborations, the stronger their impact upon non-technological organizational innovation, can be accepted. The overall fit of the model is significant: *F*-value = 9,694 with p < 0,001. Besides, the relation between external non-R&D collaborations and organizational innovation is significant: with a B-value of 0,562 and a significance level of p = 0,006. This relationship had not been investigated often before, according to Pittaway et al. (2004). But Radicic et al. (2019) found in a sample of 312 European SMEs that there is a relation between cooperating with suppliers, private and public sector institutions and an increased probability of

introducing organizational innovations. The acceptance of H3 is in line with this previously performed research.

The fourth hypothesis, **H4**: the greater the number of external non existing-R&D collaborations, the stronger their impact upon non-technological product-service innovation, can also be accepted. Both the total model as well as the model parameters are significant: the model has a *F*-value of 9,108 with a significance level of $p < 0{,}001$ and the B-value of external non-R&D collaborations is 0,317 and significant ($p = 0{,}009$). This hypothesis was not based on previous research, since that is not available, but based on a presumption that because external non-R&D collaborations affect technological process innovation and non-technological product innovation positively, it would also affect non-technological product-service innovation that way. So this finding does not match with an existing source, but is entirely new to literature.

4.5.4 Summary

In summary, the hypotheses on technological innovation cannot be accepted and the hypotheses on the non-technological innovations can be accepted. For process innovation goes that the model was significant, but the relation between external non-R&D collaborations is not, while for product innovation the model in itself was not significant. This was taken into account and for this reason a mediation analysis will be performed for product innovation. For the latter two hypotheses can be stated that the more external non-R&D collaborations firms have, the more non-technologically innovative they are. Table 14 provides an overview of the tested hypotheses.

Hypothesis	Status
H1: The greater the number of external non-R&D collaborations, the stronger their impact upon technological process innovation.	Rejected
H2a: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation.	Rejected
H3: The greater the number of external non-R&D collaborations, the stronger their impact upon non-technological organizational innovation.	Accepted
H4: The greater the number of external non-R&D collaborations, the stronger their impact upon non-technological product-service innovation.	Accepted

Table 14: Overview of the tested hypotheses with help of regression analyses

4.6 Mediation analysis

To test if the relationship between external non-R&D collaborations and product innovation goes via R&D, as stated in hypothesis 2b, mediation analyses will be conducted. This is done on the basis of these two conceptual models:

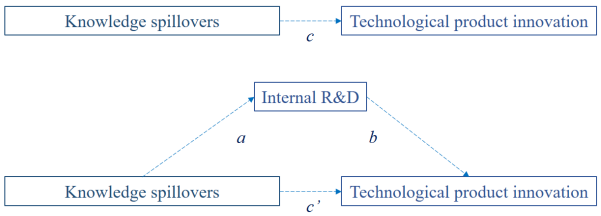


Figure 4: Conceptual model of the mediating variable internal R&D

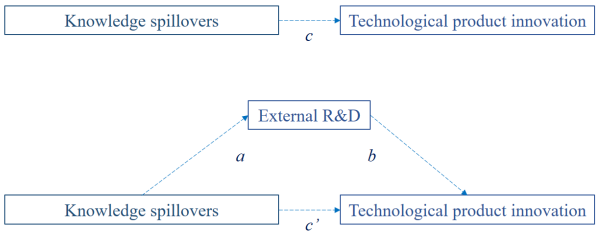


Figure 5: Conceptual model of the mediating variable external R&D

As can be seen in both conceptual models, the mediation analysis consists of four paths. Namely a, b c and c'. For internal R&D question 15.2 'How is the staff in your company location distributed among the following areas of activity?', of the EMS is used and for external R&D 6.1 'Is your business location cooperating with other companies on R&D with purchasers and suppliers and / or with research institutions?'. Both variables have a metric measurement level.

4.6.1 Mediating analysis for internal R&D

There was no significant indirect effect of external non-R&D collaborations on product innovation through internal R&D, $b = 0{,}01$, 95% CI [-0,251, 0,521].

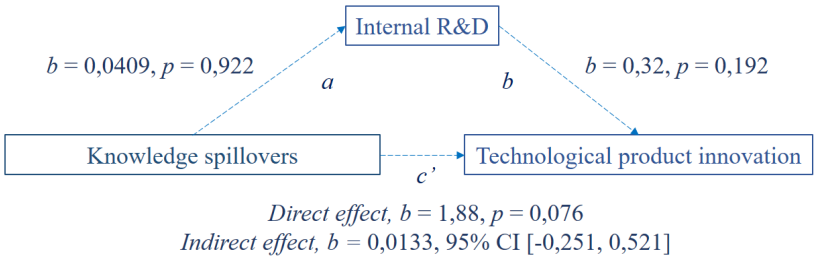


Figure 6: Values of the paths with internal R&D as mediator

4.6.2 Mediating analysis for external R&D

There was no significant indirect effect of external non-R&D collaborations on product innovation through external R&D, b = 0,28, 95% CI [-,313, 1,022].

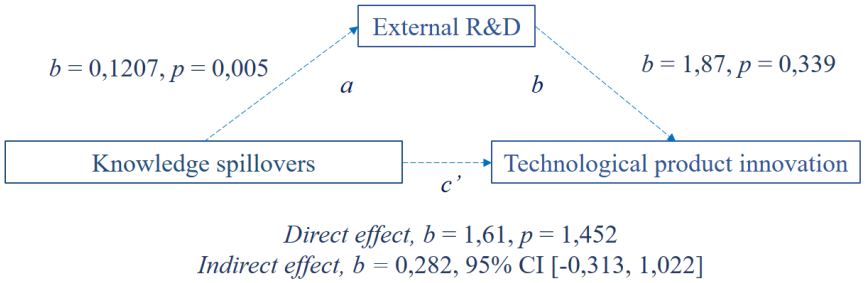


Figure 7: Values of the paths with external R&D as mediator

4.6.3 Hypothesis

The hypothesis for which the mediation analysis had been conducted, reads: **H2b**: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation via R&D collaborations. This hypothesis cannot be accepted because both mediation analyses turned out to be non-significant. Audretsch and Feldman (1996), Hervas-Oliver et al. (2011) and Xie et al. (2019) all found proof that the relation between non-R&D activities and product innovation via R&D is significant. Why that is not the case in this research remains unanswered.

Hypothesis	Status
H2b: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation via R&D collaborations.	Rejected

Table 15: Overview of the tested hypothesis with help of mediation analyses

5. Conclusion

In this chapter the main points will be summarized and a conclusion will be drawn. This will be done by answering the sub questions and lastly the research question.

Knowledge spillovers are not fully interpreted yet. There is literature present about the topic, though it is not complete, nor unambiguous. This starts with the actual definition of knowledge spillovers, whether that only entails unintentional flows of tacit knowledge, or also encompasses intentional flows of codified knowledge. This gap continues by the sources of knowledge spillovers, as well as in the relationship between knowledge spillovers and innovation being not certain. There is literature present that this relation exists, but other authors claim it does not, and still others say that the outcomes of knowledge spillovers are unpredictable, because the movement of knowledge is unpredictable.

Innovation has four appearances, based on Schumpeter's theories. Technological innovations can be distinguished in: process innovation, the implementation of a new or significantly improved production or delivery method and in product innovation, which entails the introduction of goods, services or technologies that are new or significantly improved. The two non-technological innovation types are: organizational innovation, which is the development and implementation of new organizational methods, and product-service innovation, what encompasses the delivery of a new service.

Research and development is creative work done systematically to increase knowledge.

This study is meant to find out more about the relation between knowledge spillovers and the different types of innovation. Often research on innovation looks at R&D, while a lot of firms are innovative without performing R&D. External non-R&D collaborations are used as a derivate variable for knowledge spillovers, given that knowledge flows cannot be traced. The used methods to look into these correlations are literature study, regression analysis and mediation analysis. For this latter two a sample of 175 Dutch industrial firms is used.

What these analyses yielded will be explained by answering the sub questions and the focal question of this study.

To what extent do external non-R&D collaborations generate knowledge spillovers affecting technological process innovation? This relationship was expected to be positive, so the corresponding hypothesis to this question is **H1**: The greater the number of external non-

R&D collaborations, the stronger their impact upon technological process innovation. This hypothesis is rejected because the relationship between predictor and dependent variable did not turn out to be significant. Hence, this sub question can be answered with that external non-R&D collaborations do not generate knowledge spillovers affecting process innovation.

For the second sub question: *To what extent do external non-R&D collaborations generate knowledge spillovers affecting technological product innovation?,* with the associated hypothesis **H2a**: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation, the answer is also that external non-R&D collaborations do not generate knowledge spillovers affecting technological product innovation. The hypothesis had to be rejected because the regression model to test for this, did not turn out to be significant.

The third sub question reads: *To what extent do external non-R&D collaborations generate knowledge spillovers indirectly affecting technological product innovation via R&D?*. **H2b**: The greater the number of external non-R&D collaborations, the stronger their impact upon technological product innovation via R&D, belongs to this question but has to be rejected. Both mediation analyses on internal R&D and external R&D were not significant, so external non-R&D collaborations do not generate knowledge spillovers indirectly affecting technological product innovation via R&D.

The fourth sub question is *To what extent do external non-R&D collaborations generate knowledge spillovers affecting non-technological organizational innovation?*. This relationship was anticipated to be positive, so the according hypothesis is **H3:** The greater the number of external non-R&D collaborations, the stronger their impact upon non-technological organizational innovation. Both the regression analysis model fit, as well as the model parameters turned out to be significant and positive. Consequently, this sub question can be answered with: external non-R&D collaborations do generate knowledge spillovers affecting non-technological organizational innovation.

The last sub question of this paper is: *To what extent do external non-R&D collaborations generate knowledge spillovers affecting non-technological product-service innovation?*. The attached hypothesis here is **H4:** The greater the number of external non-R&D collaborations, the stronger their impact upon non-technological product-service innovation. This sub question can be answered with that external non-R&D collaborations do generate knowledge spillovers affecting non-technological product-service innovation,

because the executed regression analysis was significant and the relationship between independent and dependent variable also was significant, and positive.

Now that we have the answers to the sub questions, it is time to answer the focal question of this research:

In which respect do external non-R&D collaborations generate knowledge spillovers affecting innovativeness in industrial companies?

External non-R&D collaborations only generate knowledge spillovers affecting non-technological innovativeness in industrial companies. So the technological innovativeness of industrial companies is not affected by external non-R&D collaborations. External non-R&D collaborations turned out to only have an effect on non-technological organizational innovation and non-technological product-service innovation, but not on technological process innovation or technological product innovation, not even indirectly through R&D.

6. Discussion

This chapter evaluates the performed research by reflecting on the theory, discussing the contribution and limitations of the analyses and providing recommendations for further research and policy plans.

6.1 Reflection on theory

The output of this research does not match with the existing literature on this topic. Firstly there were clues that the relationship between knowledge spillovers and process innovation would be significantly positive, while this research showed that this relation is not significant. The same applies for product innovation, although the non-significant result fitted to some literal pieces. But those pieces found significance in the indirect relation with R&D as mediator, while here that relation was not significant. For organizational innovation, the outcomes were suchlike in similar studies. Product-service innovation was not tested to be correlated to knowledge spillovers before, so this result is an addition to literature.

6.2 Scientific contribution

The contribution this study has to the literature is that the relationship between external non-R&D collaborations and product-service innovation has been investigated, and been found significantly positive. There was no research available yet on this topic. As for the correlation between external non-R&D collaborations and organizational innovation, this had been researched before, but not often so this contributes to the generalizability of the relation. Another contribution is the literature study that was conducted, this showed that there are several definitions of knowledge spillovers, sometimes even contradicting each other's. This can be confusing and not convenient when researchers both mean something else while talking about the same concept.

6.3 Limitations

As for the limitations of this paper, this research only being focused on quantitative data will be the largest. Three of the five hypotheses had to be rejected, but the empirical analysis did not provide an answer why the relations are not significant and positive. If this research would also include a qualitative part, this could be investigated by means of in depth-interviews. On the other hand, it would not be possible to conduct a lot of interviews considering the time limit. So the generalizability of the qualitative research would be very little.

Another limitation was that the survey was already set out, the data was secondary so it was not possible to change the questions that were asked in the questionnaire. Now the variables for process, organizational and product-service innovation were based on the

number of implemented innovations, while product innovation was based on the percentage of turnover the firms received from newly introduced products. So not all four dependent variables were measured the same way.

Lastly, the population of the research is still quite narrow. It focussed on Dutch manufacturing firms, and although these manufacturing firms will be similar to the ones abroad, 175 valid respondents is not enough to generalize for the whole manufacturing industry in Europe.

6.4 Recommendations

The positive side of these limitations is that they create opportunities for new research. First of all, it can be investigated why knowledge spillovers turn out to not have an effect on technological innovations, not even via R&D. Secondly, as written above this paper only researched Dutch manufacturing firms while it would also be interesting to look into the relationships in other countries / continents. Another research recommendation would be to test the relationship over a longer period of time. It could be that the hypotheses on technological innovation were not significant because it takes longer to implement these. So to test for this, a longer time frame could be used.

Besides recommendations for further research, this paper also yielded some managerial recommendations. It turns out that external non-R&D collaborations generate knowledge spillovers that affect organizational and product-service innovation in a positive way. So firms that would like to implement such innovations, as should be every firm considering the importance of innovation for survival, should be involved in external non-R&D collaborations. For technological innovation this statement cannot be made because the relationship between external non-R&D collaborations and technological innovation was not significant. This also applies to the indirect effect of external non-R&D collaborations on technological product innovation via R&D.

Bibliography

Agarwal, R., Ganco, M., & Ziedonis, R. H. (2009). Reputations for toughness in patent enforcement: implications for knowledge spillovers via inventor mobility. *Strategic Management Journal*, *30*(13), 1349-1374. https://doi.org/https://doi.org/10.1002/smj.792

Armbruster, H., Bikfalvi, A., Kinkel, S., & Lay, G. (2008). Organizational innovation: The challenge of measuring non-technical innovation in large-scale surveys. *Technovation*, *28*(10), 644-657. https://doi.org/https://doi.org/10.1016/j.technovation.2008.03.003

Armbruster, H., Kirner, E., & Lay, G. (2006). *Patterns of Organisational Change in European Industry (PORCH): Ways to Strengthen the Empirical Basis of Research and Policy; DG Enterprise and Industry: Innovation Policy Unit. Final report*. Fraunhofer Inst. Systems and Innovation Research. https://books.google.nl/books?id=2abBlAEACAAJ

Arrow, K. J. (1962). The Economic Implications of Learning by Doing. *The Review of Economic Studies*, *29*(3), 155-173. https://doi.org/10.2307/2295952

Arundel, A., Bordoy, C., & Kanerva, M. (2007). Neglected innovators: How do innovative firms that do not perform R&D innovate. *Results of an analysis of the Innobarometer*, *9*.

Audretsch, D., & Belitski, M. (2021). Frank Knight, uncertainty and knowledge spillover entrepreneurship. *Journal of Institutional Economics*, 1-27. https://doi.org/10.1017/S1744137421000527

Audretsch, D. B., Belitski, M., & Caiazza, R. (2021). Start-ups, Innovation and Knowledge Spillovers. *The Journal of Technology Transfer*, *46*(6), 1995-2016. https://doi.org/10.1007/s10961-021-09846-5

Audretsch, D. B., & Feldman, M. P. (1996). R&D Spillovers and the Geography of Innovation and Production. *The American Economic Review*, *86*(3), 630-640. http://www.jstor.org/stable/2118216

Bhandari, P. (2021, 4 May 2022). *Control variables | What Are They & Why Do They Matter?* Retrieved 8 June 2022 from https://www.scribbr.com/methodology/control-variable/

Bogliacino, F., & Vivarelli, M. (2012). THE JOB CREATION EFFECT OF R&D EXPENDITURES*. *Australian Economic Papers*, *51*(2), 96-113. https://doi.org/https://doi.org/10.1111/j.1467-8454.2012.00425.x

Bronzini, R., & Piselli, P. (2016). The impact of R&D subsidies on firm innovation. *Research Policy*, *45*(2), 442-457. https://doi.org/https://doi.org/10.1016/j.respol.2015.10.008

Burt, Ronald S. (2004). Structural Holes and Good Ideas. *American Journal of Sociology*, *110*(2), 349-399. https://doi.org/10.1086/421787

Carlino, G. (2001). Knowledge spillovers: Cities' role in the new economy. *Business Review*, *7*, 17-26.

Cowan, R., David, P., & Foray, D. (1999). The Explicit Economics of Knowledge Codification and Tacitness. *Industrial and Corporate Change*, *9*.

Davies, G. H., Flanagan, J., Bolton, D., Roderick, S., & Joyce, N. (2021). University knowledge spillover from an open innovation technology transfer context. *Knowledge Management Research & Practice*, *19*(1), 84-93. https://doi.org/10.1080/14778238.2020.1746204

De Noni, I., Orsi, L., & Belussi, F. (2018). The role of collaborative networks in supporting the innovation performances of lagging-behind European regions. *Research Policy*, *47*(1), 1-13. https://doi.org/https://doi.org/10.1016/j.respol.2017.09.006

Döring, T., & Schnellenbach, J. (2006). What do we know about geographical knowledge spillovers and regional growth?: A survey of the literature. *Regional Studies*, *40*(3), 375-395. https://doi.org/10.1080/00343400600632739

Fallah, M., Wesley, P., Howe, J., Ibrahim, S., & Howe, W. (2004). Knowledge spillover and innovation in technological clusters. *Proceedings of the IAMOT Conference*.

Fenwick, T. (2003). Innovation: Examining workplace learning in new enterprises. *Journal of Workplace Learning*, *15*, 123-132. https://doi.org/10.1108/13665620310468469

Fershtman, C., & Gandal, N. (2011). Direct and indirect knowledge spillovers: the "social network" of open-source projects. *The RAND Journal of Economics*, *42*(1), 70-91. http://www.jstor.org/stable/23046790

Field, A. (2018). *Discovering statistics using IBM SPSS Statistics* (J. Seaman, Ed. 5 ed.). SAGE publications Ltd. .

Fischer, M. M. (2006). *Innovation, networks, and knowledge spillovers: selected essays*. Springer Science & Business Media.

Fritsch, M., & Franke, G. (2004). Innovation, regional knowledge spillovers and R&D cooperation. *Research Policy*, *33*(2), 245-255. https://doi.org/https://doi.org/10.1016/S0048-7333(03)00123-9

Ghio, N., Guerini, M., Lehmann, E. E., & Rossi-Lamastra, C. (2015). The emergence of the knowledge spillover theory of entrepreneurship. *Small Business Economics*, *44*(1), 1-18. https://doi.org/10.1007/s11187-014-9588-y

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., & Shleifer, A. (1992). Growth in cities. *Journal of political economy*, *100*(6), 1126-1152.

Granovetter, M. S. (1973). THE STRENGTH OF WEAK TIES. *American Journal of Sociology*, *78*(6), 1360-1380. https://doi.org/10.1086/225469

Guerrero, M., & Urbano, D. (2014). Academics' start-up intentions and knowledge filters: an individual perspective of the knowledge spillover theory of entrepreneurship. *Small Business Economics*, *43*(1), 57-74. https://doi.org/10.1007/s11187-013-9526-4

Hair, J., Black W., Babin B., Anderson R. (2019). *Multivariate data analysis* (8 ed.). Cengage.

Hervas-Oliver, J.-L., Albors Garrigos, J., & Gil-Pechuan, I. (2011). Making sense of innovation by R&D and non-R&D innovators in low technology contexts: A forgotten lesson for

policymakers. *Technovation*, *31*(9), 427-446. https://doi.org/https://doi.org/10.1016/j.technovation.2011.06.006

Hervás-Oliver, J.-L., Parrilli, M. D., Rodríguez-Pose, A., & Sempere-Ripoll, F. (2021). The drivers of SME innovation in the regions of the EU. *Research Policy*, *50*(9), 104316. https://doi.org/https://doi.org/10.1016/j.respol.2021.104316

Hervas-Oliver, J.-L., Sempere-Ripoll, F., Boronat-Moll, C., & Rojas, R. (2015). Technological innovation without R&D: unfolding the extra gains of management innovations on technological performance. *Technology Analysis & Strategic Management*, *27*(1), 19-38. https://doi.org/10.1080/09537325.2014.944147

Hirsch-Kreinsen, H. (2008). LowTech Innovations. *Industry and Innovation*, *15*(1), 19-43.

Hollanders, H., & ter Weel, B. (2002). Technology, knowledge spillovers and changes in employment structure: evidence from six OECD countries. *Labour Economics*, *9*(5), 579-599. https://doi.org/https://doi.org/10.1016/S0927-5371(02)00056-8

Høyrup, S. (2012). Employee-Driven Innovation: A New Phenomenon, Concept and Mode of Innovation. In (pp. 3-33). https://doi.org/10.1057/9781137014764_1

Huang, C., Arundel, A., & Hollanders, H. (2007). *Non-R&D innovation of manufacturing firms: Theory and evidence from the third European community innovation survey*. European Commission.

Jaffe, A. B., Trajtenberg, M., & Fogarty, M. S. (2000). Knowledge spillovers and patent citations: Evidence from a survey of inventors. *American Economic Review*, *90*(2), 215-218.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. (1993). Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *The Quarterly Journal of Economics*, *108*(3), 577-598. https://doi.org/10.2307/2118401

Jirjahn, U., & Kraft, K. (2011). Do Spillovers Stimulate Incremental or Drastic Product Innovations? Evidence from German Establishment Data*. *Oxford Bulletin of Economics and Statistics*, *73*(4), 509-538. https://doi.org/https://doi.org/10.1111/j.1468-0084.2010.00618.x

Johnson, B. (2002). Why all this fuss about codified and tacit knowledge? *Industrial and Corporate Change*, *11*(2), 245-262. https://doi.org/10.1093/icc/11.2.245

Kim, G. H., & Park, I. K. (2015). Agglomeration economies in knowledge production over the industry life cycle: evidence from the ICT industry in the Seoul Capital Area, South Korea. *International Journal of Urban Sciences*, *19*(3), 400-417. https://doi.org/10.1080/12265934.2015.1083461

Klevorick, A. K., Levin, R. C., Nelson, R. R., & Winter, S. G. (1995). On the sources and significance of interindustry differences in technological opportunities. *Research Policy*, *24*(2), 185-205. https://doi.org/https://doi.org/10.1016/0048-7333(93)00762-I

Konno, T. (2016). Knowledge spillover processes as complex networks. *Physica A: Statistical Mechanics and its Applications*, *462*, 1207-1214. https://doi.org/10.1016/j.physa.2016.06.124

Krugman, P. (1992). *Geography and trade*. MIT press.

Lasagni, A. (2012). How Can External Relationships Enhance Innovation in SMEs? New Evidence for Europe*. *Journal of Small Business Management*, *50*(2), 310-339. https://doi.org/10.1111/j.1540-627X.2012.00355.x

Laskowska-Rutkowska, A. (2008). Poland's Innovation Policy vs. EU Strategy in Support of Innovation in Services. *Zagreb International Review of Economics and Business*, *11*, 31-49.

Lee, C., Lee, K., & Pennings, J. M. (2001). Internal capabilities, external networks, and performance: a study on technology-based ventures. *Strategic Management Journal*, *22*(6-7), 615-640. https://doi.org/https://doi.org/10.1002/smj.181

Lopez-Rodriguez, J., & Martinez-Lopez, D. (2017). Looking beyond the R&D effects on innovation: The contribution of non-R&D activities to total factor productivity growth in the EU. *Structural Change and Economic Dynamics*, *40*, 37-45. https://doi.org/https://doi.org/10.1016/j.strueco.2016.11.002

Mairesse, J., & Mohnen, P. (2004). The Importance of R&D for Innovation: A Reassessment Using French Survey Data. *The Journal of Technology Transfer*, *30*(1), 183-197. https://doi.org/10.1007/s10961-004-4365-8

Ngo, Q. (2020). SMEs' in-house R& D, outsourced R& D or both: The supply-chain FDI linkages and technology transfer. *Uncertain Supply Chain Management*, *8*(4), 821-830.

NWO. (n.d.). *Nederlandse gedragscode wetenschappelijke integriteit*. https://www.nwo.nl/nederlandse-gedragscode-wetenschappelijke-integriteit

OECD. (2002). *Frascati Manual 2002*. https://doi.org/doi:https://doi.org/10.1787/9789264199040-en

OECD. (2005). Oslo manual: GUIDELINES FOR COLLECTING AND INTERPRETING INNOVATION DATA. *Paris and Luxembourg: OECD/Euro-stat, na dan*, *19*, 2021. https://doi.org/https://doi.org/10.1787/9789264013100-en

OECD, & Communities, S. O. o. t. E. (2005). *Oslo Manual*. https://doi.org/doi:https://doi.org/10.1787/9789264013100-en

Perri, A., & Peruffo, E. (2016). Knowledge Spillovers from FDI: A Critical Review from the International Business Perspective. *International Journal of Management Reviews*, *18*(1), 3-27. https://doi.org/10.1111/ijmr.12054

Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. (2004). Networking and Innovation: A Systematic Review of the Evidence. *International Journal of Management Reviews*, *5*, 137-168. https://doi.org/10.1111/j.1460-8545.2004.00101.x

Radicic, D., Douglas, D., Pugh, G., & Jackson, I. (2019). COOPERATION for INNOVATION and ITS IMPACT on TECHNOLOGICAL and NON-TECHNOLOGICAL INNOVATIONS: EMPIRICAL EVIDENCE for EUROPEAN SMES in TRADITIONAL MANUFACTURING INDUSTRIES. *International Journal of Innovation Management*, *23*(5). https://doi.org/10.1142/S1363919619500464

Sanchez, R., & Heene, A. (1997). Reinventing strategic management: New theory and practice for competence-based competition. *European Management Journal*, *15*(3), 303-317.

Schmidt, T. (2006). An empirical analysis of the effects of patents and secrecy on knowledge spillovers. *ZEW-Centre for European Economic Research Discussion Paper*(06-048).

Serrano-Domingo, G., & Cabrer-Borrás, B. (2017). Direct and indirect knowledge spillovers and industrial productivity. *Industry and Innovation*, *24*(2), 165-189. https://doi.org/10.1080/13662716.2016.1224706

Singh, J. (2005). Collaborative Networks as Determinants of Knowledge Diffusion Patterns. *Management science*, *51*(5), 756-770.

Teece, D. J., Rumelt, R., Dosi, G., & Winter, S. (1994). Understanding corporate coherence: Theory and evidence. *Journal of Economic Behavior & Organization*, *23*(1), 1-30. https://doi.org/https://doi.org/10.1016/0167-2681(94)90094-9

Tödtling, F., & Grillitsch, M. (2014). Types of Innovation, Competencies of Firms, and External Knowledge Sourcing—Findings from Selected Sectors and Regions of Europe. *Journal of the Knowledge Economy*, *5*(2), 330-356. https://doi.org/10.1007/s13132-012-0139-y

Trachuk, A., & Linder, N. (2019). Knowledge Spillover Effects: Impact of Export Learning Effects on Companies' Innovative Activities. In. IntechOpen. https://doi.org/10.5772/intechopen.86255

Van Stel, A. J., & Nieuwenhuijsen, H. R. (2004). Knowledge Spillovers and Economic Growth: An Analysis Using Data of Dutch Regions in the Period 1987–1995. *Regional Studies*, *38*(4), 393-407. https://doi.org/10.1080/03434002000213914

Vernon Henderson, J. (2007). Understanding knowledge spillovers. *Regional Science and Urban Economics*, *37*(4), 497-508. https://doi.org/https://doi.org/10.1016/j.regsciurbeco.2006.11.010

Xie, X., Wang, H., & Jiao, H. (2019). Non-R&D innovation and firms' new product performance: the joint moderating effect of R&D intensity and network embeddedness. *R&D Management*, *49*(5), 748-761. https://doi.org/https://doi.org/10.1111/radm.12369

Yang, H., Phelps, C., & Steensma, H. K. (2010). LEARNING FROM WHAT OTHERS HAVE LEARNED FROM YOU: THE EFFECTS OF KNOWLEDGE SPILLOVERS ON ORIGINATING FIRMS. *The Academy of Management Journal*, *53*(2), 371-389.

Yang, H., & Steensma, H. K. (2014). When do firms rely on their knowledge spillover recipients for guidance in exploring unfamiliar knowledge? *Research Policy*, *43*(9), 1496-1507. https://doi.org/https://doi.org/10.1016/j.respol.2014.04.016

Appendices

Overview of the appendices

Appendix 1 EMS questionnaire

Radboud Universiteit Nijmegen
Institute for Management Research

Modernisering van de productie
Enquête 2015

Deze vragenlijst heeft als doel inzicht te krijgen in de inspanningen van industriële bedrijven in Nederland om hun productie en bedrijfsprocessen te moderniseren. Het onderzoek richt zich op productiebedrijven met een omvang van tenminste 10 werknemers. Bij ondernemingen met meerdere vestigingen hebben de vragen betrekking op de aangeschreven vestiging en niet op de totale onderneming.

Voor het onderzoek is beantwoording van alle vragen van belang. Ook als niet alle genoemde technologieën of organisatieconcepten van toepassing zijn op uw bedrijfsvestiging, verzoeken wij u vriendelijk de vragenlijst toch volledig in te vullen.

Voor vragen kunt u terecht bij. dr. Peter Vaessen E-Mail: P.Vaessen @ fm.ru.nl Tel.: 024 3611266 Fax: 024 3611933

1.1 **Is uw bedrijfsvestiging** (kruis slechts één optie aan):

- Het hoofdkantoor van een onderneming/groep met ook buitenlandse vestigingen
- Een dochter/divisie van een buitenlandse onderneming/groep
- Het hoofdkantoor van een onderneming/groep met alleen binnenlandse vestigingen
- Een dochter/divisie van een onderneming/groep met alleen binnenlandse vestigingen
- Een zelfstandige onderneming

1.2 Bedrijfstak (bijv. textiel, chemische industrie, machinebouw, enz.): hoofdproductgroep aandeel van hoofd-product (groep) in omzet ca. %

1.3 **Is uw bedrijfsvestiging gelet op uw hoofdproduct(groep) leverancier van eindfabricaten of een toeleverancier van onderdelen/ materialen of bewerkingen?** (Kruis slechts één optie aan)

producent van eindfabricaten		toeleverancier		aanbieder van bewerkingen
voor consumenten	voor bedrijven	van systemen/ installaties	van halffabricaten/ onderdelen	aanbieder van bewerkingen (draaien, coaten, lassen, vermalen, e.a.)

1.4 **Als u uw hoofdproduct(groep) levert aan andere bedrijven (als eindfabrikant of toeleverancier), aan welke bedrijfstak levert u dan hoofdzakelijk?** (Kruis slechts één optie aan)

Machinebouw | Chemische industrie | Automotive industrie | Elektro-techniek | andere bedrijfstak, nl.:

1.5 **In hoeverre voert uw bedrijfsvestiging voor het hoofdproduct de volgende activiteiten uit van het waardecreatieproces?**
Kruis voor elke activiteit aan in welke mate die in uw eigen bedrijfsvestiging dan wel elders wordt uitgevoerd.
Kruis ook aan of een activiteit in het geheel geen deel uitmaakt van het waardecreatieproces

	Waardecreatie-activiteiten					
	Onderzoek en Ontwikkeling	Ontwerp/ Vormgeving	Productie/ Verwerking/Recycling	Assemblage	Onderhoud/ Dienstverlening	Verpakken/ Distributie
grotendeels intern > 85%						
relevant deel intern (25%-85%)						
klein deel intern (<25%)						
niet nodig voor vervaardiging van het hoofdproduct						

2 **Hoe belangrijk zijn de volgende factoren voor de concurrentiepositie van uw bedrijfsvestiging?** (geef de volgorde van belangrijkheid aan met een score van 1 tot 6; 1 is het belangrijkst, gebruik elke score slechts één keer)

productprijs	productkwaliteit	innovatieve producten	aanpassing producten aan klantenwensen	tijdige levering/ korte levertijden	dienstverlening en service

3 **Welke van de volgende organisatieconcepten en werkwijzen worden momenteel in uw bedrijfsvestiging toegepast?**

Toepassing gepland voor 2018	Nee	Organisatieconcepten	Ja	Voor het eerst toegepast[1]	Omvang van het toegepaste potentieel[2]
		Organisatie van het werk			
	☐	Gedetailleerde voorschriften voor de werkplekinrichting van apparatuur en opslag van tussenproducten (bijv. 5-S methode)	☐	19/20	g m h
	☐	Gestandaardiseerde en gedetailleerde werkinstructies	☐	19/20	g m h
	☐	Taakverrijking productiemedewerker (integratie van planning, uitvoering of controle)	☐	19/20	g m h
		Organisatie van de productie			
	☐	Maatregelen ter verbetering van de interne logistiek (Value Stream Mapping/Design, ruimtelijke inrichting van productiestappen)	☐	19/20	g m h
	☐	Klant- of productgeoriënteerde inrichting van productie-eenheden (i.t.t. functionele indeling)	☐	19/20	g m h
	☐	Vraaggestuurde productie (bijv. KANBAN, afschaffen van tussenvoorraden)	☐	19/20	g m h
	☐	Voorgeschreven methoden voor het verkorten van omstel- en aanlooptijden bij productwisseling (bijv. Single Minute Exchange of Die; Quick Change Over)	☐	19/20	g m h
		Productiemanagement/ -beheersing			
	☐	Grafische weergave werkprocessen en -status (Visual Management; dashboard)	☐	19/20	g m h
	☐	Kwaliteitsmanagement (bijv. preventieve onderhoud, total quality management/TQM, total productie-onderhoud/TPM)	☐	19/20	g m h
	☐	Methoden voor operation management o.b.v. wiskundige analyse van productie (bijv. Six Sigma methode)	☐	19/20	g m h
	☐	Methoden van continu verbeteren (Kaizen, kwaliteitscirkels e.d.)	☐	19/20	g m h
		Energie- en milieubeheersing			
	☐	Gecertificeerd energie-management systeem volgens ISO 50001, voorheen: EN 16001	☐	19/20	g m h
	☐	Instrumenten voor productlevenscyclus-analyse (bijv. EU Ecolabel, Cradle-to-Cradle certificaat, ISO-14020)	☐	19/20	g m h
	☐	Het opnemen van sociale en duurzaamheidseffecten in het vaststellen van bedrijfsprestaties	☐	19/20	g m h
		Human resource management			
	☐	Maatregelen voor het behoud van oudere werknemers of hun kennis voor uw bedrijfsvestiging (bijv. teams met verschillende leeftijdsgroepen, begeleidingsprogramma's, senior-junior tandems)	☐	19/20	g m h
	☐	Instrumenten ter bevordering van werknemersbetrokkenheid (bijv. gratis kantine, ondersteuning kinderopvang, gezinsvriendelijke werktijden)	☐	19/20	g m h
	☐	Gestandaardiseerde methoden van functie-ontwerp ter verbetering van gezondheids- en veiligheidsomstandigheden op het werk (bijv. Methods-time measurement (MTM))	☐	19/20	g m h
	☐	Financiële participatie toegankelijk voor alle werknemersgroepen (bijv. winstdelingsregelingen, aandelen(optie)plannen, enz.)	☐	19/20	g m h

Toelichting:
1 Het jaar waarin deze technologie voor het eerst werd toegepast in uw bedrijfsvestiging (maak een schatting indien u onzeker bent over het exacte jaar)
2 Daadwerkelijke toepassing ten opzichte van maximaal zinvolle toepassingsmogelijkheden: omvang van het gebruikte potentieel is "gering" bij eerste aanzetten, "midden" bij gedeeltelijke toepassing en "hoog" bij omvangrijke toepassing

4.1 **Welke van de volgende activiteiten worden uitgevoerd voor uw productiepersoneel in uw bedrijfsvestiging?**

Aanwezige competenties van productiewerknemers worden systematisch vastgelegd? ☐ nee ☐ ja
Functiebeschrijvingen zijn ontwikkeld voor specifieke functiegebieden in de productie? ☐ nee ☐ ja
Er bestaan specifieke competentieprogramma's for bepaalde functies ☐ nee ☐ ja

4.2 **Bij welke personeelsgroepen worden deze instrumenten gebruikt?**

☐ LBO of ongeschoold personeel ☐ MBO geschoold personeel ☐ Hooggeschoold personeel (HBO+WO)

4.3 **Bestaat er afzonderlijk beleid voor competentie-ontwikkeling en training van productiepersoneel?**

☐ nee ☐ ja → Is er in uw bedrijf voor dit beleid een vast jaarlijks budget beschikbaar? ☐ nee ☐ ja

5.1 **Is er een vastgesteld aantal dagen per jaar voor verdere kwalificatie, training en ontwikkeling van het productiepersoneel?**

☐ nee ☐ ja → **Hoeveel dagen per jaar is er per persoon vastgesteld?** ca. ____ dagen per jaar

5.2 **Zijn de volgende activiteiten voor verdere kwalificatie, training en ontwikkeling toegepast voor het productiepersoneel in uw bedrijfsvestiging?**

	nee	ja	In aanmerking komen de volgende groepen van productiepersoneel: LBO of ongeschoold	MBO technisch geschoold	Hooggeschoold (WO+HBO)
Training voor specifieke vaardigheden (bijv. machine-onderhoud)	☐	☐→			
Training met interdisciplinair oogmerk (bijv. taalcursussen, leiderschapstraining)	☐	☐→			
Digitale zelfscholingprogramma's (e-learning)	☐	☐→			
On-the-job training (bijv. taakrotatie, werkplekinstructie, georganiseerde ervaringsuitwisseling met collega's)	☐	☐→			
Informatie-aanbod (bijv. bedrijfstak specifieke beurzen, externe databases)	☐	☐→			
Deelname aan activiteiten voor continue kwaliteitsverbetering (bijv. kwaliteitscirkels, Kaizen)	☐	☐→			

6.1 **Werkt uw bedrijfsvestiging samen met andere bedrijven op de volgende terreinen?**
(samenwerking = vrijwillige samenwerking die verder gaat dan eenmalige transacties tussen bedrijven)

	nee	ja	Locatie van de partners: regionaal (< 50km)	nationaal (> 50km)	buiten-land
Samenwerking in inkoop	☐	☐→			
Samenwerking in de productie (voor gezamenlijke systeemleveringen of capaciteitsuitbreiding)	☐	☐→			
Samenwerking in distributie/verkoop	☐	☐→			
Samenwerking in service	☐	☐→			
Samenwerking in onderzoek en ontwikkeling met afnemers of leveranciers	☐	☐→			
Samenwerking in onderzoek & ontwikkeling (O&O) met onderzoeksinstituten (bijv. universiteiten, TNO)	☐	☐→			

6.2 **Indien uw bedrijfsvestiging voor onderzoek en ontwikkeling samenwerkt met andere bedrijven, zijn daarbij bedrijven actief op het gebied van nanotechnologie, micro-elektronica, photonen, nieuwe materialen, of biotechnologie?**

☐ nee ☐ ja → ☐ nanotechnologie ☐ micro-elektronica ☐ photonen ☐ nieuwe materialen ☐ biotechnologie

7.1 **Welke van de volgende maatregelen zijn genomen om het risico van industriële spionage te vermijden in uw bedrijfsvestiging? Sinds wanneer zijn deze ingevoerd?**

	nee	ja	sinds wanneer?
Speciale IT-veiligheidsmaatregelen (bijv. geen gebruik cloud computing, versleutelen van documenten, algemeen verbod op gebruik van draagbare data media)	☐	☐→	19/20
Werknemerstrainingen en verhoging van waakzaamheid voor het gevaar van industriële spionage	☐	☐→	19/20
Veiligheidsmaatregelen voor toegang tot terrein, gebouwen of kamers	☐	☐→	19/20
Veiligheidsinstructies over illegale verspreiding van informatie (bijv. regelingen voor omgaan met gevoelige gegevens in relatie tot derde partijen)	☐	☐→	19/20

7.2 **Heeft uw bedrijfsvestiging te maken gehad met spionage door andere bedrijven, buitenlandse overheidsorganisaties of met verdachte gevallen in de laatste vijf jaar?**

concre(e)t(e) geval(len) ☐ nee ☐ ja → ☐ ander bedrijf ☐ buitenlandse overheidsorganisatie ☐ onbekend

verdacht(e) geval(len) ☐ nee ☐ ja → ☐ ander bedrijf ☐ buitenlandse overheidsorganisatie ☐ onbekend

7.3 **Indien er sprake was van een verdacht of concreet geval, welke informatie was het doelwit van industriële spionage?**

Informatie over....

☐ Producten (bijv. ideeën, studies, ontwikkeling, ontwerp) ☐ Productie- of fabricageprocessen ☐ Klanten/toeleveranciers (bijv. contracten, prijzen) ☐ Bedrijfsstrategie (bijv. investeringsplannen)

8.1 **Welke van de volgende technologieën worden momenteel in uw bedrijfsvestiging toegepast?**

Toepassing gepland voor 2018	Nee	Technologieën	Ja	Voor het eerst gebruikt (Jaar)[1]	upgrade sinds 2012: Ja	upgrade sinds 2012: Nee	Omvang van het toegepaste potentieel[2]
		Automatisering en robotisering					
	☐	Industriële robots voor bewerking en fabricage (bijv. lassen, coaten, snijden)	☐	19/20	☐	☐	g m h
	☐	Industriële robots voor hanteren van gereedschap en werkstukken in productie (bijv. verplaatsen, assemblage, sorteren, verpakken)	☐	19/20	☐	☐	g m h
		Energie- en grondstoffenbesparing					
	☐	Controlesystemen die machines stilleggen bij onderbenutting (bijv. PROFI-energy)	☐	19/20	☐	☐	g m h
	☐	Geautomatiseerde beheerssystemen voor energie efficiënte productie	☐	19/20	☐	☐	g m h
	☐	Systemen t.b.v. terugwinning van kinetische en procesenergie (bijv. terugwinnen afvalwarmte)	☐	19/20	☐	☐	g m h
	☐	Technologieën voor energie- en/of warmteopwekking door middel van zon-, wind-, waterkracht, biomassa of geothermische energie	☐	19/20	☐	☐	g m h
		Bewerkingstechnologieën voor nieuwe materialen					
	☐	Productietechnologieën voor micromechanische componenten (micromachinale bewerking, lithografie, micro-injectie e.d.)	☐	19/20	☐	☐	g m h
	☐	Nanotechnologische productieprocessen (bijv. oppervlaktebewerking)	☐	19/20	☐	☐	g m h
	☐	Technieken voor verwerking van composietmateralen (bijv. carbonvezel, glasvezel)	☐	19/20	☐	☐	g m h
	☐	Bio- en gentechnologie in fabricageprocessen (bijv. catalysatoren, bioreactoren)	☐	19/20	☐	☐	g m h
	☐	Technieken voor verwerking van legeringen (aluminium-, magnesium-, titaniumlegeringen, enz.)	☐	19/20	☐	☐	g m h
		Additieve productietechnologieën					
	☐	Additive productietechnologie voor maken van prototypes (bijv. 3D printing, rapid prototyping; Selective Laser Sintering; Stereolithografie, Laser Beam Melting)	☐	19/20	☐	☐	g m h
	☐	Productie met additieve productietechnologie (incl. enkelstuksproductie; kleine productieseries; reserveonderdelen)	☐	19/20	☐	☐	g m h
	☐	Systemen voor Machine2Machine communicatie, Multi-agent systemen	☐	19/20	☐	☐	g m h
	☐	Systemen voor Cyber-Physical systems, cloud-computing	☐	19/20	☐	☐	g m h
		Digitale fabriek / IT netwerken					
	☐	Digitale productieplanning en roostering (bijv. ERP-systeem)	☐	19/20	☐	☐	g m h
	☐	Bijna real-time productiebeheersingssystemen (bijv. systemen voor gecentraliseerde aansturing en machinegegevensverwerking	☐	19/20	☐	☐	g m h
	☐	Digitale uitwisseling van productieplanningsgegevens met toeleveranciers en/of klanten (supply chain management)	☐	19/20	☐	☐	g m h
	☐	Systemen voor geautomatiseerd management van interne logistiek en orderverzameling (e.g. RFID, warehouse management system)	☐	19/20	☐	☐	g m h
	☐	Mobiele/draadloze apparaten voor programmering en bediening van installaties en machines (e.g. tablets)	☐	19/20	☐	☐	g m h
	☐	Product Lifecycle Management (PLM) systemen of Product/Productieproces datamanagement	☐	19/20	☐	☐	g m h
	☐	Technologieën voor veilige mens-machine interactie (bijv. coöperatieve robots, open werkstations e.d.)	☐	19/20	☐	☐	g m h
	☐	Digitale oplossingen voor het direct beschikbaar maken van tekeningen, werkschemas en -instructies op de werkvloer (e.g. tablets, smartphones)	☐	19/20	☐	☐	g m h

Toelichting:

1 Het jaar waarin deze technologie voor het eerst werd toegepast in uw bedrijfsvestiging (maak een schatting indien u onzeker bent over het exacte jaar)

2 Daadwerkelijke toepassing ten opzichte van maximaal zinvolle toepassingsmogelijkheden: omvang van het gebruikte potentieel is "gering" bij eerste aanzetten, "midden" bij gedeeltelijke toepassing en "hoog" bij omvangrijke toepassing

8.2 Welke van de volgende maatregelen nam uw bedrijfsvestiging om energieverbruik te verminderen?

	Toepassing gepland voor 2018	nee	ja
Afschakelsystemen voor onderdelen, machines of installaties indien niet in gebruik (bijv. afschakeling luchttoevoer, aangepaste verlichtingssensoren)		☐	☐
Verbeteren van bestaande machines of installaties (bijv. hoogefficiënte motoren (IE3), aanbrengen isolatie, warmtewisseleraar)		☐	☐
Voortijdige vervanging van bestaande machines of installaties door nieuwe machines of installaties		☐	☐

8.3 Welke van de volgende redenen en welke van de genoemde barrières zijn van doorslaggevende betekenis voor het wel of niet invoeren van energie en warmte opwekkende technologieën op basis van hernieuwbare energie in uw vestiging?

Redenen voor invoering	Energie	Warmte	Belangrijke barrières	Energie	Warmte
Verwachte ontwikkeling van de energieprijzen	☐	☐	Te grote investeringen of voordelen ontbreken	☐	☐
Strategische redenen (bijv. "groen imago")	☐	☐	Administratieve last (bijv. goedkeuringsprocedures)	☐	☐
Terugdringen broeikasgassen	☐	☐	Niet van toepassing in deze bedrijfsvestiging	☐	☐
Eigen energie-opwekking ter vergroting aantal energiebronnen	☐	☐	Vooralsnog geen relevant onderwerp in deze vestiging	☐	☐
Politieke of wettelijke bepalingen	☐	☐	Andere barrières	☐	☐

9.1 Heeft uw bedrijf sinds 2012 producten geïntroduceerd die nieuw waren voor uw bedrijf of die technisch ingrijpend zijn vernieuwd?
(Bijv. door nieuwe grondstoffen of materialen te gebruiken, veranderingen in productiefuncties of werking e.d.)

☐ nee ☐ ja → Hoe groot was het aandeel van deze producten in de omzet van het jaar 2014? ca. ____ %

→ Hoe lang duurde gemiddeld genomen de ontwikkeling van zo'n product? (van productidee tot en met lancering) ca. ____ maanden

9.2 Hebben deze productvernieuwingen ook geleid tot betere milieu-effecten bij gebruik of verwijderen van deze nieuwe producten?

☐ nee ☐ ja → Welke verbeteringen in de milieu-effecten zijn met deze producten bereikt? (Kruis aan wat van toepassing is)

- ☐ Vermindering van gezondheidsrisico's bij gebruik
- ☐ Vermindering van energieverbruik bij gebruik
- ☐ Vereenvoudiging van onderhoud of herstel
- ☐ Verlenging productlevensduur
- ☐ Vermindering van milieuvervuiling bij gebruik (van grond, water, lucht, of geluid)
- ☐ Verbeterde recycling, terugwinning of verwijderingseigenschappen

9.3 Bevonden zich bij deze nieuwe producten (nieuw sinds 2012) ook producten, die nieuw-voor-de-markt waren en die uw bedrijfsvestiging als eerste op de markt introduceerde?

☐ nee ☐ ja → Wat was hun aandeel in de omzet van 2014? ca. ____ %

→ Zijn deze producten speciaal ontwikkeld vooral voor (kruis slechts één optie aan):

- ☐ bestaande klanten binnen uw huidige markt
- ☐ aantrekken van nieuwe klanten binnen uw huidige markt
- ☐ toetreding tot markten nieuw voor *uw bedrijfsvestiging*
- ☐ het ontwikkelen van geheel nieuwe markten

9.4 Heeft uw bedrijfsvestiging producten in het programma die u al langer dan 10 jaar aanbiedt?

☐ nee ☐ ja → Welk percentage van de omzet hadden deze producten in 2014? ca. ____ %

10.1 Welke van de volgende productgerelateerde diensten biedt u uw klanten aan?
Als uw bedrijfsvestiging dergelijke diensten aanbiedt, worden zij dan ook aangeboden voor producten van andere bedrijven?

	nee	ja	Voor producten van andere bedrijven
Installatie, inbedrijfstelling	☐	☐ →	
Onderhoud en reparatie	☐	☐ →	
Training	☐	☐ →	
Ontwerp, technisch advies (incl. testen, simulaties, O&O voor klanten)	☐	☐ →	
Software-ontwikkeling (bijv. software-aanpassing)	☐	☐ →	
Klantondersteuning op afstand (helpdesk, service hotline, website)	☐	☐ →	
Reviseren, vernieuwen (incl. functie opwaardering of software-uitbreidingen)	☐	☐ →	
End-of-life dienstverlening (bijv. recycling, opheffen, terugname)	☐	☐ →	

10.2 **Indien u productgerelateerde diensten aanbiedt, hoe hoog schat u het aandeel daarvan in de totale omzet van 2014?**
► In geval van geen omzet, vul in „0".

Aandeel in totale omzet van diensten die u in 2014 direct, d.w.z. apart, in rekening heeft gebracht ca. ____ %

Aandeel van diensten die u in 2014 indirect in rekening heeft gebracht (via de productprijs) ca. ____ %

10.3 **Heeft uw bedrijfsvestiging vanaf 2012 nieuwe productgerelateerde diensten aangeboden, die geheel nieuw zijn voor uw bedrijfsvestiging of belangrijke verbeteringen bevatten?**

[ ] nee [ ] ja → Hoe groot was het aandeel in de omzet van 2014 van deze sinds 2012 nieuw aangeboden productgerelateerde diensten, die uw bedrijfsvestiging direct of indirect in rekening heeft gebracht? ca.. ____ %

11 **Hoe vaak heeft uw organisatie vanaf 2012 de volgende activiteiten verricht?**

		(0=niet; 1=1 keer; 2=vaker)
Spin-offs	Opstarten van nieuwe organisaties of activiteiten buiten de onderneming	0 1 2
Uitgaand intellectueel eigendom	Verkopen, of aanbieden van licenties/patenten aan andere organisaties	0 1 2
Werknemer-betrokkenheid	Benutten van kennis en initiatieven van niet-O&O medewerkers bij het realiseren van innovaties	0 1 2
Klantbetrokkenheid	Direct betrekken van klanten in uw innovatieprocessen	0 1 2
Extern netwerken	Het samenwerken met andere organisaties (niet klanten) voor innovatie	0 1 2
Externe participatie	Deelnemen (met bijv. vermogen, kennis) in ondernemingen om toegang te krijgen tot hun kennis of om andere synergieën te creëren?	0 1 2
Uitbesteden van O&O	Uitbesteden van O&O (diensten) aan andere organisaties, zoals universiteiten, publieke onderzoeksinstellingen, commerciële ingenieurs of leveranciers?	0 1 2
Inkomend intellectueel eigendom	Kopen of in licentie nemen van intellectueel eigendom van andere organisaties	0 1 2

12. **Hoe hebben zich in uw bedrijfsvestiging de productiekosten per eenheid product (eenheidskosten) ontwikkeld in 2014?**

Gedaald met 10% of meer	Gedaald 5 - < 10%	Gedaald 0 - < 5%	Gelijk gebleven	Gestegen 0 - < 5%	Gestegen 5 - < 10%	Gestegen met 10% of meer
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

13 **In de voorafgaande vragen heeft u informatie gegeven over verschillende velden van innovatie. Rangorden deze innovatievelden naar mate van belangrijkheid voor uw bedrijfsvestiging.**
Geef met een score van 1 tot 4 de volgorde van belangrijkheid aan met 1 als het belangrijkst; gebruik elke score slechts één keer.

Toevoegen van diensten aan uw producten	Organisatie-vernieuwing	Technische vernieuwing in het productieproces	Ontwikkeling van nieuwe producten
◯	◯	◯	◯

14 **Welke van de onderstaande informatiebronnen zijn het meest relevant voor belangrijke innovatie-impulsen/ideeën in uw bedrijfsvestiging op de volgende gebieden?** (Kruis maximaal drie informatiebronnen aan voor elk gebied van innovatie)

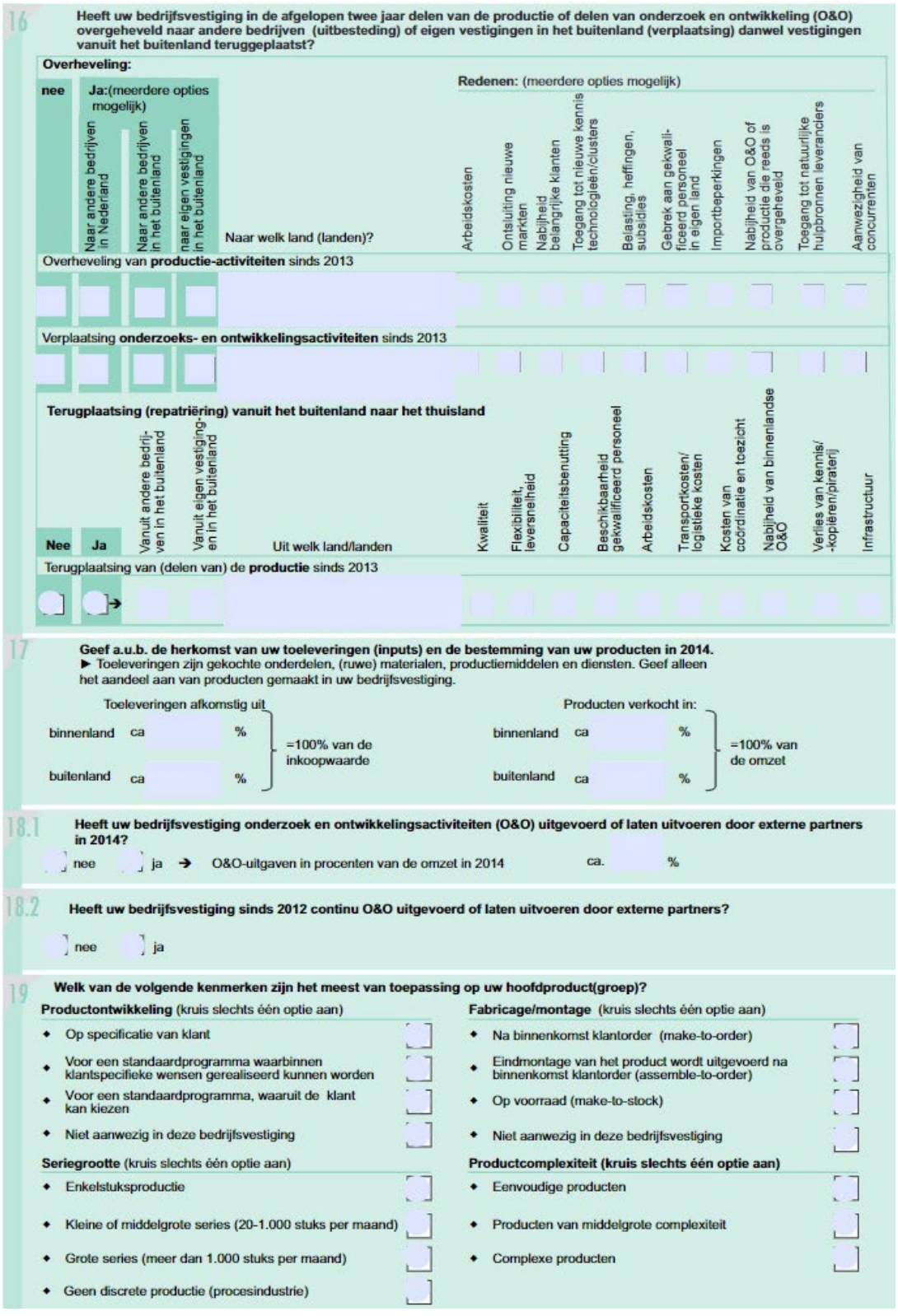
	intern				extern			
	O&O, engineering	productie-afdeling	Klanten-service	Leiding bedrijfsvestiging	Klant of gebruiker	Leverancier	Onderzoeks-instellingen, universiteiten	Conferenties, beurzen
Nieuwe producten								
Nieuwe proces-technologieën								
Nieuwe diensten								
Nieuwe organisatie-concepten								

15.1 **Wat is het opleidingsniveau van het personeel van uw bedrijfsvestiging?**

Hoger onderwijs (HBO+WO)	ca. ____ %	=100%
MBO technische opleiding	ca. ____ %	
MBO adminstratieve en commerciële opleiding	ca. ____ %	
LBO of ongeschoold	ca. ____ %	
Personeel in opleiding (leerlingen, stagiaires)	ca. ____ %	

15.2 **Hoe is het personeel in uw bedrijfsvestiging verdeeld over de volgende werkterreinen:**

Onderzoek en ontwikkeling	ca. ____ %	=100%
Ideevorming, ontwerp en vormgeving	ca. ____ %	
Fabricage en montage	ca. ____ %	
Klantenservice	ca. ____ %	
Overige (administratie, inkoop, logistiek/distributie, onderhoud, productieplanning enz.)	ca. ____ %	



16 **Heeft uw bedrijfsvestiging in de afgelopen twee jaar delen van de productie of delen van onderzoek en ontwikkeling (O&O) overgeheveld naar andere bedrijven (uitbesteding) of eigen vestigingen in het buitenland (verplaatsing) danwel vestigingen vanuit het buitenland teruggeplaatst?**

Overheveling:

nee | **Ja:**(meerdere opties mogelijk) Naar andere bedrijven in Nederland | Naar andere bedrijven in het buitenland | naar eigen vestigingen in het buitenland | Naar welk land (landen)? | **Redenen:** (meerdere opties mogelijk) Arbeidskosten | Ontsluiting nieuwe markten | Nabijheid belangrijke klanten | Toegang tot nieuwe kennis technologieën/clusters | Belasting, heffingen, subsidies | Gebrek aan gekwalificeerd personeel in eigen land | Importbeperkingen | Nabijheid van O&O of productie die reeds is overgeheveld | Toegang tot natuurlijke hulpbronnen leveranciers | Aanwezigheid van concurrenten

Overheveling van **productie-activiteiten** sinds 2013

Verplaatsing **onderzoeks- en ontwikkelingsactiviteiten** sinds 2013

Terugplaatsing (repatriëring) vanuit het buitenland naar het thuisland

Nee | **Ja** | Vanuit andere bedrijven in het buitenland | Vanuit eigen vestigingen in het buitenland | Uit welk land/landen | Kwaliteit | Flexibiliteit, leversnelheid | Capaciteitsbenutting | Beschikbaarheid gekwalificeerd personeel | Arbeidskosten | Transportkosten/ logistieke kosten | Kosten van coördinatie en toezicht | Nabijheid van binnenlandse O&O | Verlies van kennis/ -kopiëren/piraterij | Infrastructuur

Terugplaatsing van (delen van) de **productie** sinds 2013

17 **Geef a.u.b. de herkomst van uw toeleveringen (inputs) en de bestemming van uw producten in 2014.**
► Toeleveringen zijn gekochte onderdelen, (ruwe) materialen, productiemiddelen en diensten. Geef alleen het aandeel aan van producten gemaakt in uw bedrijfsvestiging.

Toeleveringen afkomstig uit:
binnenland ca % } =100% van de inkoopwaarde
buitenland ca %

Producten verkocht in:
binnenland ca % } =100% van de omzet
buitenland ca %

18.1 **Heeft uw bedrijfsvestiging onderzoek en ontwikkelingsactiviteiten (O&O) uitgevoerd of laten uitvoeren door externe partners in 2014?**

nee ja → O&O-uitgaven in procenten van de omzet in 2014 ca. %

18.2 **Heeft uw bedrijfsvestiging sinds 2012 continu O&O uitgevoerd of laten uitvoeren door externe partners?**

nee ja

19 **Welk van de volgende kenmerken zijn het meest van toepassing op uw hoofdproduct(groep)?**

Productontwikkeling (kruis slechts één optie aan)
- Op specificatie van klant
- Voor een standaardprogramma waarbinnen klantspecifieke wensen gerealiseerd kunnen worden
- Voor een standaardprogramma, waaruit de klant kan kiezen
- Niet aanwezig in deze bedrijfsvestiging

Fabricage/montage (kruis slechts één optie aan)
- Na binnenkomst klantorder (make-to-order)
- Eindmontage van het product wordt uitgevoerd na binnenkomst klantorder (assemble-to-order)
- Op voorraad (make-to-stock)
- Niet aanwezig in deze bedrijfsvestiging

Seriegrootte (kruis slechts één optie aan)
- Enkelstuksproductie
- Kleine of middelgrote series (20-1.000 stuks per maand)
- Grote series (meer dan 1.000 stuks per maand)
- Geen discrete productie (procesindustrie)

Productcomplexiteit (kruis slechts één optie aan)
- Eenvoudige producten
- Producten van middelgrote complexiteit
- Complexe producten

20 **Beantwoordt u de volgende vragen over uw hoofdproduct(groep).**

Wat is de gemiddelde productietijd van uw hoofdproduct(groep)? (doorlooptijd vanaf moment dat opdracht binnenkomt bij productie tot product klaar is voor levering) ca. ____ werk-dagen of ____ uren

Hoeveel procent van de orders wordt op tijd afgeleverd? ca. ____ %

Hoeveel procent van uw productie moet na kwaliteitscontrole nabewerking ondergaan of geheel worden afgekeurd? ca. ____ %

Welk percentage van de geleverde bestellingen heeft klachten van klanten opgeleverd vanwege kwaliteitsproblemen? ca. ____ %

21 **Hier worden enkele gegevens over uw bedrijfsvestiging gevraagd:**

Jaaromzet	2014	miljoen €	2012	miljoen €	
Aantal werknemers (excl. uitzendkrachten)	2014	aantal			
Aantal werknemers dat is afgevloeid in 2014	2014	aantal			

Had uw bedrijfsvestiging uitzendkrachten in dienst in 2014? ☐ nee ☐ ja → Hoeveel uitzendkrachten waren in 2014 gemiddeld in dienst bij uw bedrijfsvestiging? ca. ____ aantal

Inkoop 2014 (ingekochte onderdelen, materialen en diensten)	miljoen €	Personeelskosten als percentage van de omzet in 2014 (incl. loonnevenkosten)	%
Afschrijvingen op machines en installaties 2014 (zonder grond en gebouwen)	miljoen €	Graad van capaciteitsbenutting (gemiddeld in 2014)	%
Investeringen in machines en installaties 2014	miljoen €	Totale energiekosten als percentage omzet 2014	%

Rendement op de omzet (vóór belasting in 2014) ☐ negatief ☐ 0 tot 2% ☐ > 2 tot 5% ☐ > 5 tot 10% ☐ > 10%

Jaar van oprichting, c.q. inschrijving bij de Kamer van Koophandel jaar: ____ Heeft uw bedrijfsvestiging een ondernemingsraad? ☐ nee ☐ ja

22.1 **Geef uw energieverbruik aan als volgt:**

Wat was het aandeel groene stroom in het totale stroomverbruik van uw bedrijfsvestiging in 2014? ca. ____ %

Hoe groot is de te verwarmen oppervlakte van uw bedrijfsvestiging? ca. ____ m^2

22.2 **Hoe heeft het stroomverbruik van uw bedrijfsvestiging zich ontwikkeld in 2014?**

Gedaald met 10% of meer	Gedaald 5 - < 10%	Gedaald 0 - < 5%	Gelijk gebleven	Gestegen 0 - < 5%	Gestegen 5 - < 10%	Gestegen met 10% of meer
☐	☐	☐	☐	☐	☐	☐

22.3 **Hoe heeft het olie- en gasverbruik van uw bedrijfsvestiging zich ontwikkeld in 2014?**

Gedaald met 10% of meer	Gedaald 5 - < 10%	Gedaald 0 - < 5%	Gelijk gebleven	Gestegen 0 - < 5%	Gestegen 5 - < 10%	Gestegen met 10% of meer
☐	☐	☐	☐	☐	☐	☐

23 **Wie is in meerderheid of exclusief eigenaar van het bedrijf waartoe uw bedrijfsvestiging behoort?**

☐ Private eigenaar/ familie ☐ Financiële investeerder (bijv durfkapitaal) ☐ Ander bedrijf (bijv. niet-financiële investeerder) ☐ stichting ☐ overige eigenaren ☐ Geen meerderheidseigenaar

→ Is de familie actief in het management? ☐ Nee ☐ Ja

Hartelijk dank voor uw bijdrage aan dit onderzoek.

Wij verzoeken u de ingevulde vragenlijst terug te sturen per e-mail naar: P.Vaessen@fm.ru.nl

of per post naar:

Radboud Universiteit Nijmegen, t.a.v Dr P.Vaessen, Antwoordnummer 1908, 6500 VC Nijmegen

Appendix 2 Cronbach's alpha values

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
v08a1 Industrial robots for manufacturing processes	5,400000	13,414	,293	,761
v08b1 Industrial robots for handling processes	5,525714	13,481	,326	,759
v08c1 Control system for shut down of machines in off-peak periods	5,702857	14,245	,216	,765
v08d1 Control-automation systems for an energy efficient production	5,668571	13,740	,399	,757
v08e1 Technologies for recuperation of kinetic and process energy	5,525714	13,837	,209	,766
v08f1 Manufacturing technologies for micromechanical and microelectrical components	5,720000	14,295	,232	,765
vnl08f1 Technologies for generation energy\ heat	5,674286	14,474	,059	,771
v08g1 Nano-technological production processes	5,697143	14,051	,311	,761
v08h1 Processing techniques for composite materials	5,668571	14,441	,070	,771
v08i1 Biotechnology / genetic engineering methods	5,748571	14,419	,305	,765
v08k1 Processing techniques for alloy construction materials	5,588571	14,002	,188	,766
v08l1 Additive manufacturing technologies for prototyping	5,560000	13,673	,284	,761
v08m1 Additive manufacturing technologies for mass production	5,531429	13,894	,193	,767
v08n1 Software for production planning and scheduling	5,017143	13,845	,197	,767
Vnl08n1 System for Machine2Machine communication	5,605714	13,597	,356	,757
v08o1 Near real-time production control system	5,411429	12,979	,427	,752
Vnl08o1 Systems for Cyber-Physical systems, cloud-computing	5,628571	13,810	,299	,761
v08p1 Digital Exchange of product/process data with suppliers / customers	5,434286	13,144	,385	,755
v08q1 Systems for automation and management of internal logistics	5,491429	13,309	,361	,756
v08r1 Mobile/wireless devices for programming and operation	5,605714	13,872	,250	,763
v08s1 Product-Lifecycle-Management-System	5,605714	13,608	,351	,758
v08t1 Technologies for safe human-machine interaction	5,645714	13,874	,295	,761
v08u1 Digital solutions for providing drawings, work schedules or work instructions directly on the shopfloor	5,405714	13,151	,373	,756
v08v1 Switching off components, machinery or equipment measures to reduce energy consumption	5,245714	12,922	,417	,752
v08w1 Upgrading existing machinery or equipment measures to reduce energy consumption	5,394286	12,769	,485	,747
v08z1 Premature substitution by new machinery or equipment measures to reduce energy consumption	5,497143	13,263	,379	,755

Reliability Statistics

Cronbach's Alpha	N of Items
,768	26

Cronbach's alpha for process innovation

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
v03a1 Method of 5S	7,6000	13,103	,424	,788
v03b1 Standardized and detailed working instruction	7,2457	13,324	,469	,786
v03c1 Integration of tasks (planning, operating or controlling functions with the machine operator)	7,2914	13,426	,396	,790
v03d1 Method of Value Stream Mapping/Design	7,4743	13,032	,445	,787
v03e1 Customer- or product-oriented lines/cells in the factory	7,4800	13,665	,262	,800
v03f1 Production controlling by pull principles	7,4514	13,203	,399	,790
v03g1 Method for optimizing of change-over time	7,7943	13,383	,414	,789
v03h1 Visual Management	7,5886	12,899	,483	,784
v03i1 Methods of assuring quality in production	7,3771	12,949	,499	,783
v03k1 Methods of operation management for mathematical analyses of production	7,8400	13,296	,486	,785
v03l1 Methods of continuous improvement of production processes	7,4686	12,595	,578	,777
v03m1 Certified energy management system	7,9714	14,419	,205	,800
v03n1 Instruments of life-cycle assessment	7,9314	14,133	,276	,797
v03o1 Impact and performance measurements of social and environmental corporate activities	7,6857	13,148	,431	,788
v03p1 Instruments to maintain elderly employees or their knowledge in the factory	7,5486	13,548	,292	,798
v03q1 Instruments for promoting staff commitment	7,3371	13,949	,210	,802
v03r1 Standardized methods of job design for improving health or safety conditions at work	7,8229	13,606	,361	,792
v03s1 Broad-based employee financial participation schemes	7,7714	13,993	,206	,802

Reliability Statistics

Cronbach's Alpha	N of Items
,801	18

Cronbach's alpha for organizational innovation

Reliability Statistics

Cronbach's Alpha	N of Items
,772	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
v10a1 product-related services Installation, start-up procedure	2,5371	3,997	,558	,733
v10b1 product-related services Maintenance and repair	2,3657	3,923	,540	,736
v10c1 product-related services Training	2,4686	4,078	,475	,748
v10d1 product-related services Design, consulting, project planing	2,2571	4,422	,280	,782
v10e1 product-related services Software development	2,6857	4,320	,517	,744
v10f1 product-related services Remote support for clients	2,4114	4,083	,456	,751
v10g1 product-related services Revamping or modernization	2,5600	3,891	,643	,718
v10h1 product-related services End of life services	2,6343	4,463	,356	,766

Cronbach's alpha for product-service innovation

Reliability Statistics

Cronbach's Alpha	N of Items
,618	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
v06a Purchasing co-operation	1,1200	1,152	,334	,594
v06b Production co-operation	1,0571	1,043	,438	,516
v06c Sales/distribution co-operation	1,1029	1,012	,491	,475
v06d Service co-operation	1,1943	1,192	,332	,593

Cronbach's alpha for external non-R&D collaborations

Reliability Statistics

Cronbach's Alpha	N of Items
,502	2

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
v06e R&D co-operation with customers or suppliers	,5429	,250	,335	.
v06f R&D co-operation with research organizations or research entities	,3771	,236	,335	.

Cronbach's alpha for external R&D collaborations

Appendix 3 Bivariate analysis

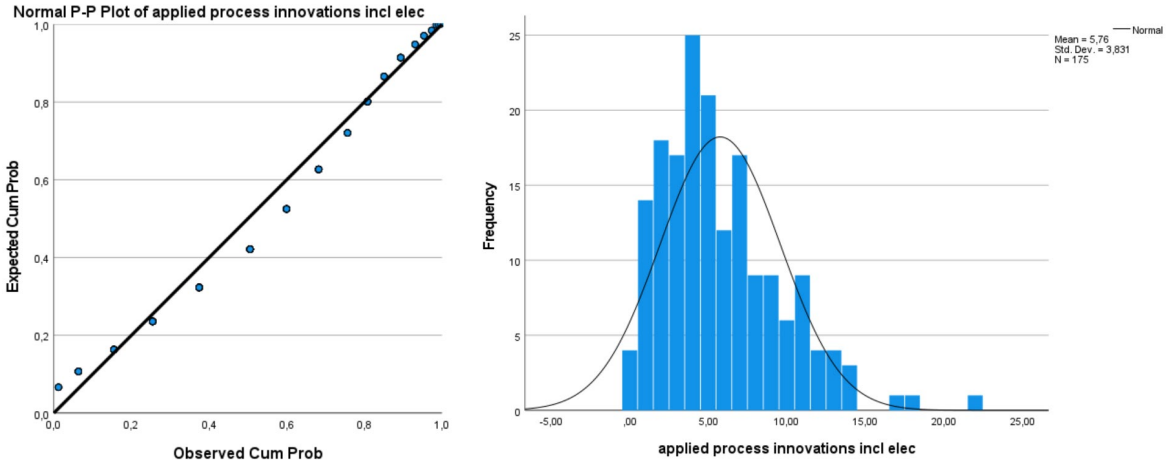
Test for multicollinearity with Pearson Correlation

	Non-R&D collaborations	Process innovation	Product innovation %	Organizational innovation	Product-service innovation	R&D collaborations	Internal R&D	Type of industry	Firm size
Non-R&D collaborations	1	,241**	,172	,302**	,267**	,267**	,064	,117	,246**
Process innovation		1	,240*	,592**	,240**	,396**	,024	,110	,527**
Product innovation			1	,143	,257**	,135	,128	,029	,041
Organizational innovation				1	,081	,380**	,096	,088	,503**
Product-service innovation					1	,211**	,328**	,336**	,130
R&D collaborations						1	,289*	,054	,246**
Internal R&D							1	,170*	-,039
Type of industry								1	,045
Firm size									1

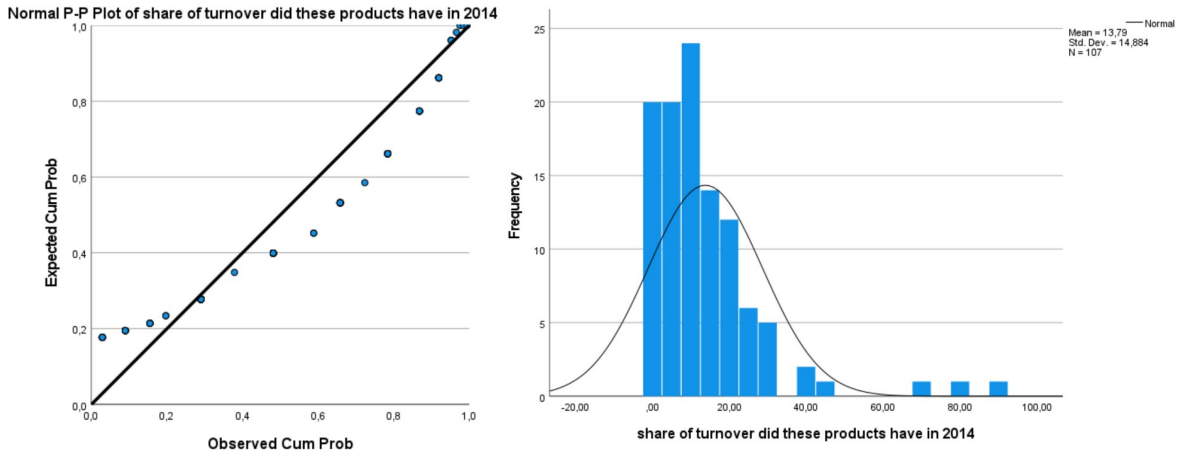
** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

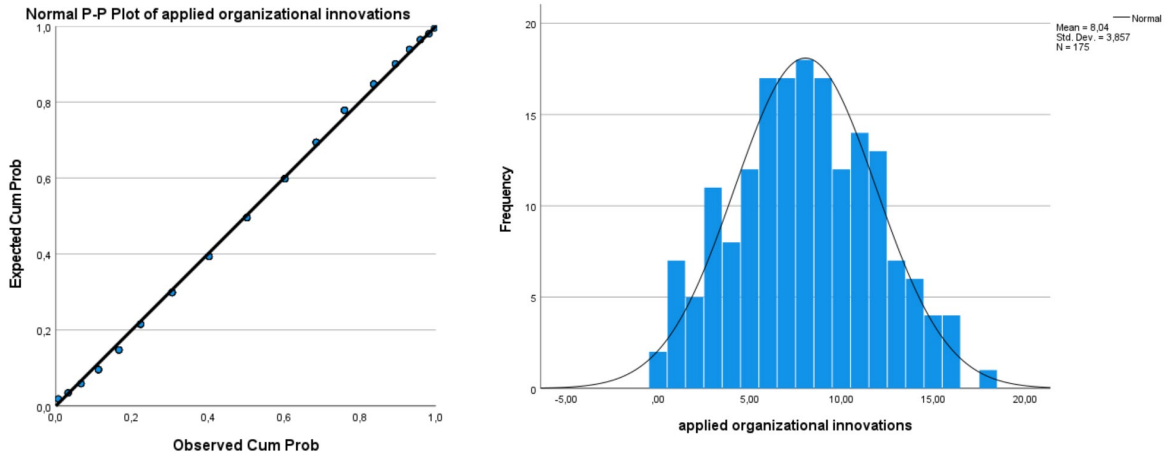
Appendix 4 Normality of the variables



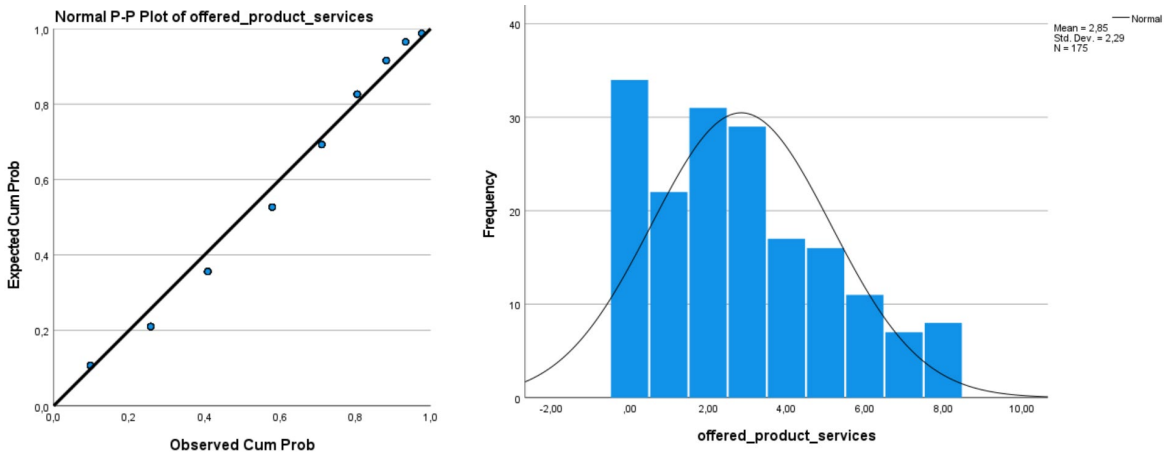
Normal P-P plot and histogram of process innovation



Normal P-P plot of product innovation



Normal P-P plot of organizational innovation



Normal P-P plot of product-service innovation

Appendix 5 Normality of product innovation after log transformation

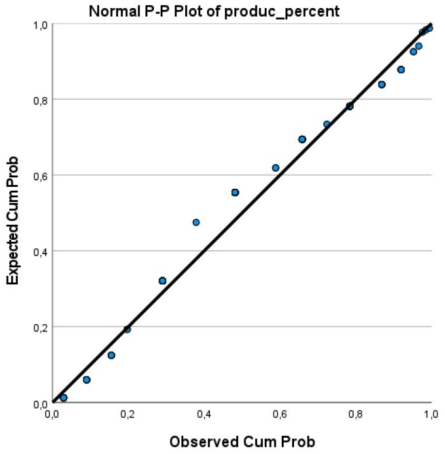
Statistics

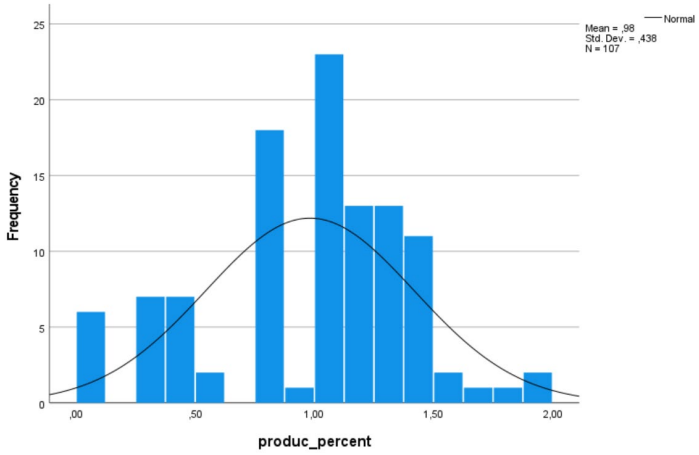
produc_percent

N	Valid	107
	Missing	68
Mean		,9817
Median		1,0414
Std. Deviation		,43781
Skewness		-,463
Std. Error of Skewness		,234
Kurtosis		-,070
Std. Error of Kurtosis		,463
Minimum		,00
Maximum		1,96

produc_percent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	6	3,4	5,6	5,6
	,30	7	4,0	6,5	12,1
	,48	7	4,0	6,5	18,7
	,60	2	1,1	1,9	20,6
	,78	18	10,3	16,8	37,4
	,95	1	,6	,9	38,3
	1,04	21	12,0	19,6	57,9
	1,11	2	1,1	1,9	59,8
	1,20	13	7,4	12,1	72,0
	1,26	1	,6	,9	72,9
	1,32	12	6,9	11,2	84,1
	1,41	6	3,4	5,6	89,7
	1,49	5	2,9	4,7	94,4
	1,61	2	1,1	1,9	96,3
	1,66	1	,6	,9	97,2
	1,85	1	,6	,9	98,1
	1,91	1	,6	,9	99,1
	1,96	1	,6	,9	100,0
	Total	107	61,1	100,0	
Missing	System	68	38,9		
Total		175	100,0		





Appendix 6 Normality of product innovation after square root transformation

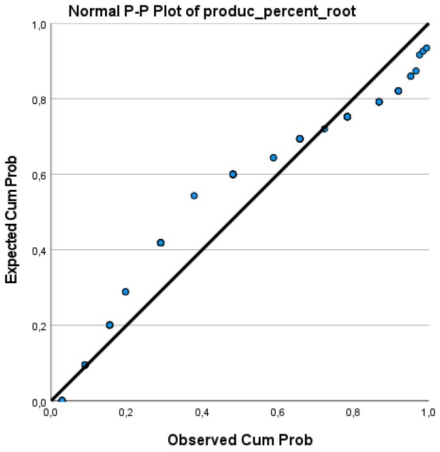
Statistics

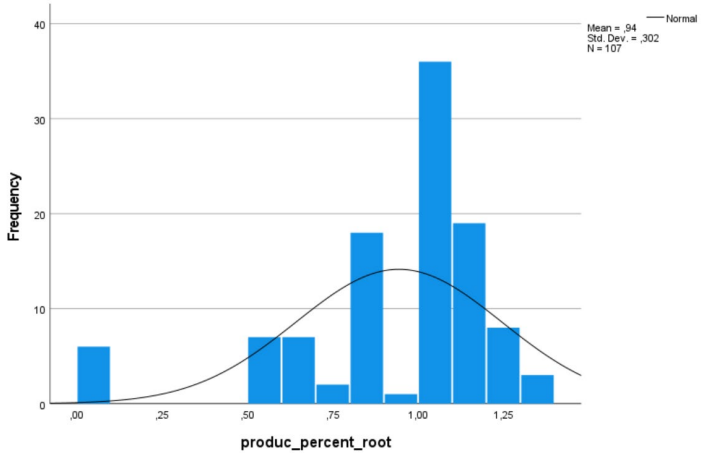
produc_percent_root

N	Valid	107
	Missing	68
Mean		,9441
Median		1,0205
Std. Deviation		,30188
Skewness		-1,707
Std. Error of Skewness		,234
Kurtosis		3,162
Std. Error of Kurtosis		,463
Minimum		,00
Maximum		1,40

produc_percent_root

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	6	3,4	5,6	5,6
	,55	7	4,0	6,5	12,1
	,69	7	4,0	6,5	18,7
	,78	2	1,1	1,9	20,6
	,88	18	10,3	16,8	37,4
	,98	1	,6	,9	38,3
	1,02	21	12,0	19,6	57,9
	1,06	2	1,1	1,9	59,8
	1,10	13	7,4	12,1	72,0
	1,12	1	,6	,9	72,9
	1,15	12	6,9	11,2	84,1
	1,19	6	3,4	5,6	89,7
	1,22	5	2,9	4,7	94,4
	1,27	2	1,1	1,9	96,3
	1,29	1	,6	,9	97,2
	1,36	1	,6	,9	98,1
	1,38	1	,6	,9	99,1
	1,40	1	,6	,9	100,0
	Total	107	61,1	100,0	
Missing	System	68	38,9		
Total		175	100,0		



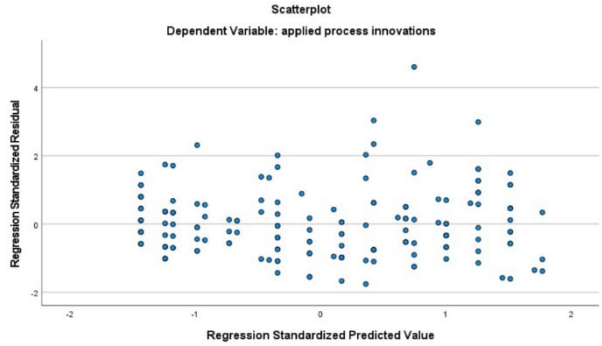


Appendix 7 Homoscedasticity of the variables with Levene's test

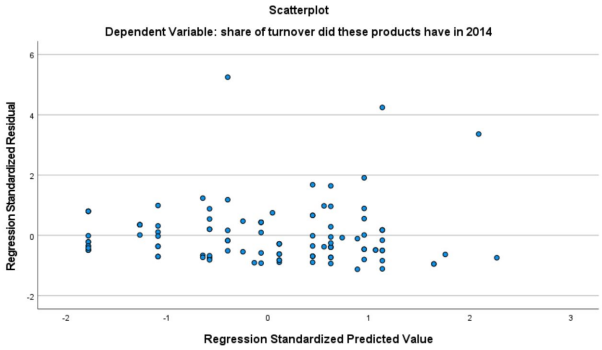
Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Process_innovs_elec applied process innovations incl elec	Based on Mean	1,231	4	102	,302
	Based on Median	1,079	4	102	,371
	Based on Median and with adjusted df	1,079	4	86,961	,372
	Based on trimmed mean	1,200	4	102	,315
Organizational_innovs applied organizational innovations	Based on Mean	,611	4	102	,655
	Based on Median	,452	4	102	,771
	Based on Median and with adjusted df	,452	4	95,181	,771
	Based on trimmed mean	,625	4	102	,646
offered_product_services	Based on Mean	2,027	4	102	,096
	Based on Median	1,541	4	102	,196
	Based on Median and with adjusted df	1,541	4	93,124	,197
	Based on trimmed mean	1,977	4	102	,104
v09b share of turnover did these products have in 2014	Based on Mean	1,905	4	102	,115
	Based on Median	1,230	4	102	,303
	Based on Median and with adjusted df	1,230	4	74,097	,306
	Based on trimmed mean	1,573	4	102	,187

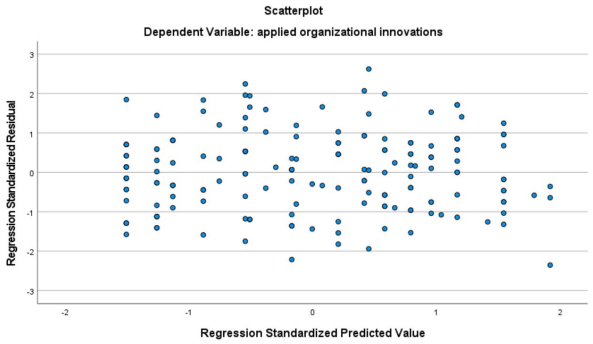
Appendix 8 Homoscedasticity of the variables with Scatterplots



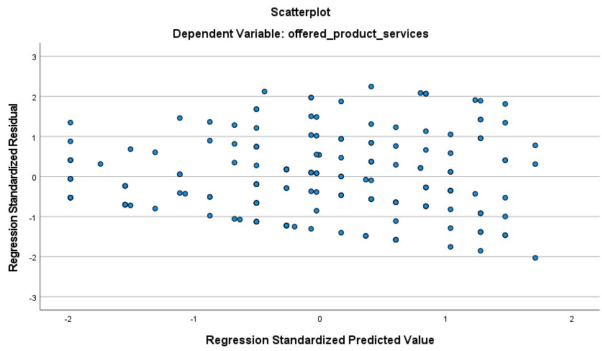
Scatterplot of the variable process innovation



Scatterplot of the variable product innovation



Scatterplot of the variable organizational innovation



Scatterplot of the variable product-service innovation

Appendix 9 Independence of errors

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,241[a]	,058	,053	3,09463	
2	,425[b]	,180	,166	2,90395	1,897

a. Predictors: (Constant), nonRD_collaborations non-R&D collaborations

b. Predictors: (Constant), nonRD_collaborations non-R&D collaborations, internal_RD internal RD present or not, RD_collaborations R&D collaborations

c. Dependent Variable: Process_innovs applied process innovations

Durbin-Watson test for process innovations

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,172[a]	,030	,020	14,73198	
2	,212[b]	,045	,017	14,75652	1,917

a. Predictors: (Constant), nonRD_collaborations non-R&D collaborations

b. Predictors: (Constant), nonRD_collaborations non-R&D collaborations, internal_RD internal RD present or not, RD_collaborations R&D collaborations

c. Dependent Variable: v09b share of turnover did these products have in 2014

Durbin-Watson test for product innovations

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,302[a]	,091	,086	3,68816	
2	,434[b]	,188	,174	3,50520	2,165

a. Predictors: (Constant), nonRD_collaborations non-R&D collaborations

b. Predictors: (Constant), nonRD_collaborations non-R&D collaborations, internal_RD internal RD present or not, RD_collaborations R&D collaborations

c. Dependent Variable: Organizational_innovs applied organizational innovations

Durbin-Watson test for organizational innovations

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,267[a]	,071	,066	2,21350	
2	,380[b]	,145	,129	2,13701	2,173

a. Predictors: (Constant), nonRD_collaborations non-R&D collaborations

b. Predictors: (Constant), nonRD_collaborations non-R&D collaborations, internal_RD internal RD present or not, RD_collaborations R&D collaborations

c. Dependent Variable: offered_product_services

Durbin-Watson test for product-service innovations

Appendix 10 Model fit

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,370[a]	,137	,127	3,58019	,137	13,625	2	172	,000
2	,446[b]	,199	,185	3,45903	,062	13,260	1	171	,000

a. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry

b. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: Process_innovs_elec applied process innovations incl elec

Model fit of the basic model for process innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,551[a]	,303	,274	3,26443	,303	10,380	7	167	,000
2	,561[b]	,315	,282	3,24651	,012	2,849	1	166	,093

a. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery

b. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: Process_innovs_elec applied process innovations incl elec

Model fit of the definitive model for process innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,481[a]	,232	,217	13,17153	,232	15,680	2	104	,000
2	,525[b]	,276	,255	12,85049	,044	6,261	1	103	,014

a. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry

b. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: v09b share of turnover did these products have in 2014

Model fit of the basic model for product innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,304[a]	,092	,028	,43161	,092	1,438	7	99	,199
2	,364[b]	,132	,061	,42414	,040	4,518	1	98	,036

a. Predictors: (Constant), employees_categories firms per size, Textile, Construction, Food, Chemical, Electronics, Machinery

b. Predictors: (Constant), employees_categories firms per size, Textile, Construction, Food, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: produc_percent_log

Model fit of the definitive model for product innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,226[a]	,051	,040	3,77936	,051	4,619	2	172	,011
2	,379[b]	,144	,129	3,59989	,093	18,578	1	171	,000

a. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry

b. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: Organizational_innovs applied organizational innovations

Model fit of the basic model for organizational innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,535[a]	,286	,256	3,32674	,286	9,559	7	167	,000
2	,564[b]	,318	,286	3,26024	,032	7,882	1	166	,006

a. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery

b. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: Organizational_innovs applied organizational innovations

Model fit of the definitive model for organizational innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,346[a]	,119	,109	2,16175	,119	11,668	2	172	,000
2	,418[b]	,174	,160	2,09940	,055	11,368	1	171	,001

a. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry

b. Predictors: (Constant), v23b1 Number of employees 2014, vIndustry, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: offered_product_services

Model fit of the basic model for product-service innovation

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,525[a]	,276	,245	1,98965	,276	9,084	7	167	,000
2	,552[b]	,305	,272	1,95489	,029	6,991	1	166	,009

a. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery

b. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

c. Dependent Variable: offered_product_services

Model fit of the definitive model for product-service innovation

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	774,281	7	110,612	10,380	,000[b]
	Residual	1779,639	167	10,657		
	Total	2553,920	174			
2	Regression	804,308	8	100,539	9,539	,000[c]
	Residual	1749,612	166	10,540		
	Total	2553,920	174			

a. Dependent Variable: Process_innovs_elec applied process innovations incl elec

b. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery

c. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1,030	,756		1,362	,175	-,463	2,523					
	Food	-,621	,942	-,049	-,659	,511	-2,480	1,239	-,033	-,051	-,043	,744	1,345
	Textile	-,658	,879	-,057	-,748	,455	-2,394	1,078	-,084	-,058	-,048	,716	1,396
	Construction	,181	1,060	,012	,170	,865	-1,912	2,274	,058	,013	,011	,788	1,270
	Chemical	-,895	,884	-,078	-1,012	,313	-2,641	,851	-,053	-,078	-,065	,708	1,412
	Machinery	,682	,803	,068	,850	,397	-,903	2,267	,139	,066	,055	,649	1,542
	Electronics	,705	,788	,071	,895	,372	-,851	2,261	,030	,069	,058	,656	1,524
	employees_categories firms per size	2,037	,253	,532	8,060	,000	1,538	2,536	,527	,529	,521	,958	1,043
2	(Constant)	,862	,759		1,136	,258	-,636	2,360					
	Food	-,656	,937	-,052	-,700	,485	-2,506	1,194	-,033	-,054	-,045	,743	1,345
	Textile	-,834	,881	-,072	-,947	,345	-2,572	,905	-,084	-,073	-,061	,706	1,416
	Construction	-,081	1,066	-,006	-,076	,939	-2,185	2,023	,058	-,006	-,005	,771	1,297
	Chemical	-1,000	,882	-,087	-1,134	,258	-2,741	,741	-,053	-,088	-,073	,705	1,419
	Machinery	,392	,816	,039	,480	,632	-1,220	2,004	,139	,037	,031	,620	1,613
	Electronics	,657	,784	,067	,838	,403	-,891	2,206	,030	,065	,054	,655	1,526
	employees_categories firms per size	1,944	,257	,508	7,558	,000	1,436	2,452	,527	,506	,486	,915	1,093
	nonRD_collaborations non-R&D collaborations	,336	,199	,116	1,688	,093	-,057	,730	,241	,130	,108	,880	1,136

a. Dependent Variable: Process_innovs_elec applied process innovations incl elec

Process innovation

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1,875	7	,268	1,438	,199[b]
	Residual	18,442	99	,186		
	Total	20,318	106			
2	Regression	2,688	8	,336	1,868	,074[c]
	Residual	17,630	98	,180		
	Total	20,318	106			

a. Dependent Variable: produc_percent_log

b. Predictors: (Constant), employees_categories firms per size, Textile, Construction, Food, Chemical, Electronics, Machinery

c. Predictors: (Constant), employees_categories firms per size, Textile, Construction, Food, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1,104	,132		8,378	,000	,842	1,365					
	Food	-,261	,159	-,189	-1,644	,103	-,576	,054	-,127	-,163	-,157	,694	1,441
	Textile	,042	,158	,030	,263	,793	-,272	,355	,121	,026	,025	,702	1,425
	Construction	-,006	,181	-,003	-,031	,975	-,366	,354	,066	-,003	-,003	,765	1,307
	Chemical	-,201	,149	-,160	-1,355	,179	-,496	,094	-,089	-,135	-,130	,654	1,530
	Machinery	-,014	,135	-,013	-,101	,920	-,282	,254	,107	-,010	-,010	,584	1,712
	Electronics	-,303	,140	-,260	-2,161	,033	-,581	-,025	-,200	-,212	-,207	,632	1,581
	employees_categories firms per size	-,006	,041	-,015	-,149	,881	-,087	,075	-,002	-,015	-,014	,945	1,058
2	(Constant)	1,073	,130		8,242	,000	,815	1,332					
	Food	-,259	,156	-,187	-1,660	,100	-,568	,051	-,127	-,165	-,156	,694	1,441
	Textile	-,009	,157	-,007	-,057	,954	-,320	,302	,121	-,006	-,005	,686	1,459
	Construction	-,042	,179	-,026	-,237	,813	-,398	,313	,066	-,024	-,022	,758	1,320
	Chemical	-,218	,146	-,174	-1,490	,139	-,508	,072	-,089	-,149	-,140	,652	1,534
	Machinery	-,063	,135	-,058	-,468	,641	-,330	,204	,107	-,047	-,044	,567	1,764
	Electronics	-,315	,138	-,270	-2,280	,025	-,588	-,041	-,200	-,224	-,215	,631	1,584
	employees_categories firms per size	-,030	,042	-,073	-,730	,467	-,113	,052	-,002	-,074	-,069	,874	1,144
	nonRD_collaborations non-R&D collaborations	,070	,033	,215	2,126	,036	,005	,135	,222	,210	,200	,862	1,160

a. Dependent Variable: produc_percent_log

Product innovation

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	740,501	7	105,786	9,559	,000[b]
	Residual	1848,219	167	11,067		
	Total	2588,720	174			
2	Regression	824,278	8	103,035	9,694	,000[c]
	Residual	1764,442	166	10,629		
	Total	2588,720	174			

a. Dependent Variable: Organizational_innovs applied organizational innovations

b. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery

c. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	2,573	,771		3,338	,001	1,051	4,094					
	Food	1,739	,960	,137	1,812	,072	-,156	3,635	,080	,139	,118	,744	1,345
	Textile	1,888	,896	,163	2,107	,037	,119	3,658	,063	,161	,138	,716	1,396
	Construction	,394	1,081	,027	,365	,716	-1,739	2,527	-,009	,028	,024	,788	1,270
	Chemical	1,872	,901	,161	2,077	,039	,092	3,651	,113	,159	,136	,708	1,412
	Machinery	1,017	,818	,101	1,244	,215	-,597	2,632	,046	,096	,081	,649	1,542
	Electronics	1,147	,803	,115	1,428	,155	-,438	2,733	-,043	,110	,093	,656	1,524
	employees_categories firms per size	1,895	,258	,491	7,358	,000	1,387	2,404	,503	,495	,481	,958	1,043
2	(Constant)	2,292	,762		3,009	,003	,788	3,796					
	Food	1,681	,941	,133	1,787	,076	-,177	3,539	,080	,137	,114	,743	1,345
	Textile	1,595	,884	,137	1,803	,073	-,151	3,341	,063	,139	,116	,706	1,416
	Construction	-,043	1,070	-,003	-,040	,968	-2,157	2,070	-,009	-,003	-,003	,771	1,297
	Chemical	1,697	,885	,146	1,917	,057	-,051	3,445	,113	,147	,123	,705	1,419
	Machinery	,533	,820	,053	,650	,516	-1,085	2,152	,046	,050	,042	,620	1,613
	Electronics	1,068	,788	,107	1,356	,177	-,487	2,623	-,043	,105	,087	,655	1,526
	employees_categories firms per size	1,740	,258	,451	6,735	,000	1,230	2,250	,503	,463	,432	,915	1,093
	nonRD_collaborations non-R&D collaborations	,562	,200	,192	2,807	,006	,167	,957	,302	,213	,180	,880	1,136

a. Dependent Variable: Organizational_innovs applied organizational innovations

Organizational innovation

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	251,731	7	35,962	9,084	,000[b]
	Residual	661,103	167	3,959		
	Total	912,834	174			
2	Regression	278,448	8	34,806	9,108	,000[c]
	Residual	634,386	166	3,822		
	Total	912,834	174			

a. Dependent Variable: offered_product_services

b. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery

c. Predictors: (Constant), employees_categories firms per size, Textile, Food, Construction, Chemical, Electronics, Machinery, nonRD_collaborations non-R&D collaborations

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1,934	,461		4,197	,000	1,024	2,844					
	Food	-1,369	,574	-,182	-2,385	,018	-2,503	-,236	-,257	-,182	-,157	,744	1,345
	Textile	-,750	,536	-,109	-1,400	,163	-1,808	,308	-,193	-,108	-,092	,716	1,396
	Construction	,327	,646	,038	,507	,613	-,948	1,603	,000	,039	,033	,788	1,270
	Chemical	,143	,539	,021	,266	,791	-,921	1,208	-,035	,021	,018	,708	1,412
	Machinery	2,528	,489	,423	5,169	,000	1,563	3,494	,444	,371	,340	,649	1,542
	Electronics	,754	,480	,128	1,570	,118	-,194	1,702	,064	,121	,103	,656	1,524
	employees_categories firms per size	,224	,154	,098	1,451	,149	-,081	,528	,130	,112	,096	,958	1,043
2	(Constant)	1,776	,457		3,887	,000	,874	2,678					
	Food	-1,402	,564	-,187	-2,486	,014	-2,516	-,288	-,257	-,189	-,161	,743	1,345
	Textile	-,916	,530	-,133	-1,727	,086	-1,963	,131	-,193	-,133	-,112	,706	1,416
	Construction	,080	,642	,009	,125	,901	-1,187	1,347	,000	,010	,008	,771	1,297
	Chemical	,045	,531	,007	,084	,933	-1,003	1,093	-,035	,007	,005	,705	1,419
	Machinery	2,255	,492	,377	4,587	,000	1,284	3,226	,444	,335	,297	,620	1,613
	Electronics	,709	,472	,120	1,502	,135	-,223	1,641	,064	,116	,097	,655	1,526
	employees_categories firms per size	,136	,155	,059	,878	,381	-,170	,442	,130	,068	,057	,915	1,093
	nonRD_collaborations non-R&D collaborations	,317	,120	,182	2,644	,009	,080	,554	,267	,201	,171	,880	1,136

a. Dependent Variable: offered_product_services

Product-service innovation

Appendix 11 Compound variables for the dummy variables

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	,862	,628		1,372	,172
	nonRD_c non-R&D collaborations	,336	,190	,116	1,769	,079
	employees_categories firms per size	1,944	,251	,508	7,758	,000
	indu_comp	1,000	,409	,155	2,445	,015

a. Dependent Variable: Process_innovs_elec applied process innovations incl elec

Process innovation

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1,073	,114		9,403	,000
	nonRD_c non-R&D collaborations	,070	,031	,215	2,230	,028
	employees_categories firms per size	-,030	,040	-,073	-,764	,447
	indu_comp_prod	1,000	,328	,281	3,044	,003

a. Dependent Variable: produc_percent_log

Product innovation

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2,292	,697		3,287	,001
	nonRD_c non-R&D collaborations	,562	,191	,192	2,943	,004
	employees_categories firms per size	1,740	,251	,451	6,924	,000
	indu_comp_orga	1,000	,355	,178	2,819	,005

a. Dependent Variable: Organizational_innovs applied organizational innovations

Organizational innovation

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1,776	,378		4,694	,000
	nonRD_c non-R&D collaborations	,317	,115	,182	2,746	,007
	employees_categories firms per size	,136	,151	,059	,903	,368
	indu_comp_ps	1,000	,133	,484	7,511	,000

a. Dependent Variable: offered_product_services

Product service innovation

Appendix 12 Outcome of the mediation analysis for internal R&D

```
**************************************************************************
Model  : 4
    Y  : v09b
    X  : nonRD_c
    M  : v15b1

Sample
Size:  107

**************************************************************************
OUTCOME VARIABLE:
 v15b1

Model Summary
          R       R-sq        MSE          F        df1        df2          p
     ,0096      ,0001    33,6222      ,0096     1,0000   105,0000      ,9221

Model
             coeff         se          t          p       LLCI       ULCI
constant    6,3218      ,8769     7,2093      ,0000     4,5830     8,0605
nonRD_c      ,0409      ,4171      ,0980      ,9221     -,7861      ,8679

**************************************************************************
OUTCOME VARIABLE:
 v09b

Model Summary
          R       R-sq        MSE          F        df1        df2          p
     ,2132      ,0455   215,5377     2,4765     2,0000   104,0000      ,0890

Model
             coeff         se          t          p       LLCI       ULCI
constant    8,6750     2,7147     3,1956      ,0018     3,2917    14,0583
nonRD_c     1,8832     1,0560     1,7833      ,0775     -,2110     3,9774
v15b1        ,3248      ,2471     1,3144      ,1916     -,1652      ,8148

Test(s) of X by M interaction:
          F        df1        df2          p
     2,4589     1,0000   103,0000      ,1199

**************************************************************************
OUTCOME VARIABLE:
 v09b

Model Summary
          R       R-sq        MSE          F        df1        df2          p
     ,1721      ,0296   217,0313     3,2032     1,0000   105,0000      ,0764

Model
             coeff         se          t          p       LLCI       ULCI
constant   10,7281     2,2279     4,8154      ,0000     6,3106    15,1456
nonRD_c     1,8965     1,0596     1,7897      ,0764     -,2046     3,9975

**************************************************************************
************** TOTAL, DIRECT, AND INDIRECT EFFECTS OF X ON Y **************

Total effect of X on Y
     Effect         se          t          p       LLCI       ULCI
     1,8965     1,0596     1,7897      ,0764     -,2046     3,9975

Direct effect of X on Y
     Effect         se          t          p       LLCI       ULCI
     1,8832     1,0560     1,7833      ,0775     -,2110     3,9774

Indirect effect(s) of X on Y:
          Effect     BootSE   BootLLCI   BootULCI
v15b1      ,0133      ,1842     -,2513      ,5212

************************ ANALYSIS NOTES AND ERRORS ************************

Level of confidence for all confidence intervals in output:
  95,0000

Number of bootstrap samples for percentile bootstrap confidence intervals:
  5000

------ END MATRIX -----
```

Appendix 13 Outcome of the mediation analysis for R&D collaborations

```
Run MATRIX procedure:

***************** PROCESS Procedure for SPSS Version 4.1 *****************

          Written by Andrew F. Hayes, Ph.D.       www.afhayes.com
    Documentation available in Hayes (2022). www.guilford.com/p/hayes3

**************************************************************************
Model  : 4
    Y  : v09b
    X  : nonRD_c
    M  : RD_colla

Sample
Size:  107

**************************************************************************
OUTCOME VARIABLE:
 RD_colla

Model Summary
         R       R-sq        MSE          F        df1        df2          p
      ,2670      ,0713      ,5449     8,0568     1,0000   105,0000      ,0054

Model
             coeff         se          t          p       LLCI       ULCI
constant      ,9059      ,1116     8,1144      ,0000      ,6845     1,1272
nonRD_c       ,1507      ,0531     2,8384      ,0054      ,0454      ,2560

**************************************************************************
             coeff         se          t          p       LLCI       ULCI
constant    10,7281     2,2279     4,8154      ,0000     6,3106    15,1456
nonRD_c      1,8965     1,0596     1,7897      ,0764     -,2046     3,9975

************** TOTAL, DIRECT, AND INDIRECT EFFECTS OF X ON Y **************

Total effect of X on Y
     Effect         se          t          p       LLCI       ULCI
     1,8965     1,0596     1,7897      ,0764     -,2046     3,9975

Direct effect of X on Y
     Effect         se          t          p       LLCI       ULCI
     1,6145     1,0999     1,4678      ,1452     -,5667     3,7958

Indirect effect(s) of X on Y:
            Effect     BootSE   BootLLCI   BootULCI
RD_colla      ,2820      ,3412     -,3134     1,0219

************************ ANALYSIS NOTES AND ERRORS ************************

Level of confidence for all confidence intervals in output:
  95,0000

Number of bootstrap samples for percentile bootstrap confidence intervals:
  5000

------ END MATRIX -----
```

```
**************************************************************************
OUTCOME VARIABLE:
 v09b

Model Summary
         R       R-sq        MSE          F        df1        df2          p
      ,1953      ,0381   217,1925     2,0614     2,0000   104,0000      ,1324

Model
             coeff         se          t          p       LLCI       ULCI
constant    9,0334     2,8429     3,1775      ,0020     3,3958    14,6710
nonRD_c     1,6145     1,0999     1,4678      ,1452     -,5667     3,7958
RD_colla    1,8708     1,9483      ,9602      ,3392    -1,9928     5,7344

Test(s) of X by M interaction:
         F        df1        df2          p
     1,2292     1,0000   103,0000      ,2702

************************ TOTAL EFFECT MODEL ************************
OUTCOME VARIABLE:
 v09b

Model Summary
         R       R-sq        MSE          F        df1        df2          p
      ,1721      ,0296   217,0313     3,2032     1,0000   105,0000      ,0764

Model
             coeff         se          t          p       LLCI       ULCI
constant   10,7281     2,2279     4,8154      ,0000     6,3106    15,1456
nonRD_c     1,8965     1,0596     1,7897      ,0764     -,2046     3,9975

************** TOTAL, DIRECT, AND INDIRECT EFFECTS OF X ON Y **************
```