Environmental Innovation and Networks

The influence of network and interaction characteristics on environmental innovative performance of companies

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Abstract

English

Companies involved in environmental innovation (EI) can be instrumental in achieving a more sustainable society. These companies are often confronted with complex and disciplinary knowledge that lies outside their own core business. This takes them to interacting with other actors in their networks. Though the relevance of networks and interaction has been researched in literature, still little is known about the specific characteristics of these concepts and their influence on environmental innovations. This research investigated the relation between network characteristics (network size and cognitive diversity) and interaction characteristics (interaction frequency, formality, informality) and environmental innovative performance. Additionally, the moderating effect of absorptive capacity on the first relation (network characteristics on EI performance) was taken into account. This was researched for the technological industry in The Netherlands, for the period of 2011 - 2013. An online questionnaire was used to collect the data after which a multiple OLS regression analysis was executed to investigate the relations. The most important findings were that for companies involved in environmental product innovations larger networks are beneficial to EI performance. Diversity of partners, interaction frequency, and formal interaction were found not to be important for those companies. Informality was shown to have a negative effect on EI performance. For companies involved in environmental process innovations larger networks are also more beneficial. Diversity of partners can be discouraged. Frequent interaction can result in higher EI performance. Formal interaction is found not to be important. Informal interaction was again shown to have a negative effect on EI performance. These findings show that there are significant differences between product and process innovations, that could be researched further. Moreover, the context of environmental innovation provided some interesting differences from what was expected based on regular innovation. This indicates that this new context must be taken into account when researching environmental innovation.

Dutch

Bedrijven die zich bezighouden met duurzame innovatie kunnen een grote rol spelen in het creëren van een duurzamere maatschappij. Deze bedrijven worden echter vaak geconfronteerd met complexe en multidisciplinaire kennis die buiten hun eigen kerncompetenties ligt. Dit zorgt er voor dat zij gaan samenwerken met andere actoren in hun netwerken. Alhoewel de relevantie van netwerken en interactie bevestigd is door de literatuur, is er nog steeds weinig kennis over de specifieke karakteristieken van deze concepten en de invloed die zij hebben op duurzame innovaties. Dit onderzoek richt zich op de relatie tussen netwerk karakteristieken (netwerk grootte en cognitieve diversiteit) en interactie karakteristieken (interactie frequentie, formaliteit en informaliteit) en duurzame innovatieve performance. Daarnaast wordt ook gekeken naar het moderatie effect van absorptive capacity op de eerste relaties (van de netwerk karakteristieken). Deze relaties zijn onderzocht voor de technologische industrie in Nederland voor de periode van 2011 tot 2013. De gegevens zijn verzameld door een online enquête uit te zetten, waarna een multipele OLS regressie analyse is uitgevoerd om de relaties te onderzoeken. De belangrijkste vindingen zijn dat voor bedrijven die zich richten op duurzame product innovaties grotere netwerken gunstig zijn voor EI performance. Diversiteit aan partners, interactie frequentie en formaliteit zijn niet van belang voor deze bedrijven. Informele interactie blijkt echter een negatieve invloed te hebben op de duurzame innovatieve performance. Voor bedrijven die zich richten op duurzame proces innovaties is een groter netwerk ook gunstig voor de duurzame performance. Diversiteit aan partners kan voor deze bedrijven echter afgeraden worden. Frequentie van interactie is daarentegen heel belangrijk voor bedrijven van duurzame proces innovaties. Formele interactie is niet van belang en informele interactie bleek een negatieve invloed te hebben op de performance. De resultaten laten zien dat er significante verschillen zijn tussen duurzame product en proces innovaties, waar nog steeds een kenniskloof bestaat en meer onderzoek nodig is. Bovendien blijkt de nieuwe context van duurzame innovatie essentieel te zijn om deze relaties te bespreken aangezien de verwachte relaties vanuit de gewone innovatie literatuur niet altijd blijken te kloppen.

Preface

This research was conducted for my Master's thesis of Innovation Sciences at Utrecht University. This final step in my Master's program was a good way to test if I am now able to use the knowledge that I acquired during my Bachelor and Master. In this research I focused on environmental innovation, because the environmental issues of the world and the sustainability of our society are subjects that are much discussed nowadays. Though this is a theme that many consider interesting, for me the more interesting part was to choose a firm-level perspective. It has always interested me how businesses deal with change and use innovation to survive and perform. A lot of research has gone into popular topics such as the science behind environmental issues, drivers for environmental innovation and how to stimulate companies to become 'greener'. However, I feel there is little research done that looks at what factors are actually important for companies that are involved in environmental innovations. This made it all the more appealing for me to investigate this area.

In the process of my thesis I have learned a lot about combining the diverse knowledge that I gained during the past couple of years. Innovation Sciences teaches you to use different perspectives to look at a problem, and to decide which perspective or theory would be most helpful in the context of your problem. In the same way I developed a theoretical framework that integrates different concepts. Even more so, I experienced that the execution of a research can be just as challenging. In my research I contacted many organizations in order to convince them to participate in my research. I encountered many people that were not willing to help, but also many that were interested. However, even the people that were interested were not always able to help. This showed me that having a good data collection strategy is essential in scientific research.

The entire thesis process took me about a year, during which I experienced both ups and downs. In dealing with some of the obstacles I had a lot of support from my thesis supervisor dr. Maryse Chappin. A special thanks to her for always being prepared to provide feedback and talk about solutions. Also, I want to thank my student counselor Pieter Louwman for motivating me endlessly.

For those of you who are interested in my thesis report, I hope you enjoy reading it.

Marja van der Werff

Index

Introduction

Environmental degradation is a hot topic in our current society. Though it is still debated by some if climate change is actually driven by human action, it is generally accepted that fundamental changes are needed to achieve a more sustainable society (Stocker et al., 2013; UNEP, 2013; EEA; 2013). Governments are working on national and international levels to form agreements and set targets to diminish the adverse effects that society has on the environment (UNFCCC, 2013; EC ,2013). Additionally, there is a growing awareness of environmental issues within society, resulting in a higher demand for sustainable products and processes (Accenture, 2012; PwC, 2012).

This stimulates companies to pursue Environmental Innovation (EI). As posed by Beise and Rennings (2005, p6) '*environmental innovations consist of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harm'.* For instance, the use of wind energy reduces harmful emissions and improved production processes can reduce toxic waste discharge (Wang & Sun, 2012; Horbach et al., 2012). The extent to which companies account for these environmental aspects in their innovations (products and/or process) is the environmental innovative performance (Lefebvre et al., 2003). Environmental innovative performance of companies can thus be instrumental in achieving a more sustainable society. There are two ways in which environmental innovation is different from regular innovation that are important to understand the context of environmental innovation.

The first difference has been named 'the double externality problem'. As is known from innovation literature, innovation is associated with externalities. Companies are not able to fully appropriate the value they create with innovations due to knowledge spill-overs to other companies. Other companies can benefit from easily accessible information about innovations. Additionally, environmental innovation does not only have to cope with these knowledge spill-overs but is also confronted with environmental externalities. As environmental innovation deals with the general welfare of people and the environment, these innovations often behave as public goods, which means that everyone can benefit from them (Jänicke, 2008; Chappin, 2008; De Marchi, 2012; Dean, 2013). For example, when a manufacturer decides to innovate its production process in such a way that it is less polluting, all people can benefit from air that has less greenhouse gasses without one person's ability to breathe the air affecting another's. This also makes it harder for companies to capture the benefits, because the externalities are harder to internalize (Dean, 2013). Thus, private companies make investments of which the public receives (a large part of) the benefits (Beise & Rennings, 2005; Jänicke, 2008; Chappin, 2008; De Marchi, 2012). This leaves those companies at a disadvantage compared to other companies because they have higher costs. Consequently, companies are less inclined to invest in environmental innovations and a market failure arises. Governmental stimulation then becomes a key determinant in the introduction of environmental innovations. Other authors argue that environmental innovation can actually provide companies with a competitive advantage over other companies that do not focus on environmental issues (Porter & Van de Linde, 1995; Shrivastava, 1995; Beise & Rennings, 2005; Eiadat et al., 2008; Forsman, 2013). Porter and Van de Linde (1995) state that the additional costs of dealing with environmental issues can be outweighed by the innovation offsets of complying with environmental standards. Extensive research has been done on regulatory and other drivers of environmental innovation (c.f. Porter & van de Linde, 1995; Rennings, 2000; Jaffe et al., 2002; Horbach et al., 2012; Triguero et al., 2013). Therefore, this research does not focus on this first difference.

The second difference is that for most companies environmental innovation does not lie in their core business. This means that often they do not possess the knowledge or resources needed to produce these innovations or implement them in their processes (Chappin, 2008; De Marchi, 2012). Experience is low and uncertainty is high, as there are no standards to follow (De Marchi, 2012). Environmental innovation, as regular innovation, cannot take place in isolation due to its nature. Companies often lack the necessary knowledge and have to look for it outside their own internal environment.

Consequently, this takes them to interacting with companies that are often new to them and have a different knowledge base (De Marchi & Grandinetti, 2013). A company's network helps transfer necessary resources and capabilities between these actors (Gulati 1998). In innovation studies the importance of resources and capabilities to gain and maintain competitive advantage has been addressed extensively (Mahoney & Pandian, 1992; Teece et al., 1997). Environmental innovation is often complex and multidisciplinary, which makes these resources and capabilities very important in order to create competitive advantage (De Marchi & Grandinetti, 2013). Though recent studies have shown the importance of these networks and relations for environmental innovation, also with suppliers and intermediaries (Cainelli et al., 2012; De Marchi, 2012), little is known about the relations of the characteristics of those networks. Innovation studies show that it is important to have a network with multiple actors that complement each other with knowledge and resources that the other does not have. Having a larger network provides more opportunities for companies to gain the needed knowledge and resources (Schilling & Phelps, 2007). Also, an optimal distance between their knowledge bases (optimal cognitive distance) is conducive of innovative performance (Boschma, 2005; Nooteboom et al., 2007). Because EI deals with high levels of multi-disciplinarity and complex knowledge, it is important for companies to interact with many different, complementary, actors. Therefore, this research looks at both network size and the cognitive diversity within the network, meaning the variety of knowledge bases of actors.

As has been indicated by innovation literature, these network characteristics and their influence on innovative performance are often influenced by the absorptive capacity of a company (Nieto & Quevedo, 2005; Zahra & Hayton, 2008; Escribano et al., 2009; Rothaermel & Alexandre, 2009). This is defined by Cohen & Levinthal (1990; p1) as: '*the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends*'. This moderating influence of absorptive capacity in the innovation context has been researched (Cohen & Levinthal, 1990; Veugelers, 1997; Tsai, 2001), but there is still little understanding about its influence within the context of environmental innovation. Therefore, the moderating effect of absorptive capacity on the relation between the network characteristics and EI performance is included in this research.

Furthermore, the importance of the way companies in a network interact with each other has been addressed in literature (Ebadi & Utterback, 1984; Mohr et al., 1996). There is little knowledge about these interaction characteristics, however, for the context on environmental innovation. There thus exists a literature gap on the interaction characteristics for environmental innovation. Literature on interaction suggests that frequency, formality and informality of interaction are three of the most important aspects of interaction and that these have a significant influence on innovative performance (Lorenzoni & Lipparini, 1999; Cavusgil et al., 2003; Lavie, 2006; Capaldo, 2007). Literature has shown the relevance of interaction in order to benefit from networks (Ebadi & Utterback, 1984; Mohr et al., 1996). However, the relevance for environmental innovation has not been researched extensively and therefore these three characteristics of interaction are addressed in this research.

The aim of this research is to gain insights into the influence of the selected network and interaction characteristics on the environmental innovative performance of companies. Furthermore, this research also aims at gaining insights into the moderating effect of absorptive capacity on the relations between the network characteristics (network size and cognitive diversity) and the environmental innovative performance. This leads to the following two-part research question:

To what extent do network and interaction characteristics influence the environmental innovative performance of companies? And to what extent is the relation between network characteristics and environmental innovative performance influenced by the absorptive capacity of a company?

In this research companies in the science-based industry within The Netherlands will be investigated, because these companies are heavily reliant on knowledge (Pavitt, 1984) and The Netherlands is a knowledge-based economy. The specific industry that is researched here is the technological industry because companies in this industry are active in EI but can still improve a lot when it comes to environmental innovation (CBS, 2014b). Therefore, this industry provides a good opportunity to look into the relations stated above.

There is a growing understanding of the importance of networking and interaction in environmental innovation. However, the actual network characteristics and interaction processes are still a black box. This research adds to existing literature by linking theories on innovation and networking and interaction to the context of environmental innovation. More specifically, the aspects of network size, cognitive diversity, interaction frequency, formality and informality, and their relation to environmental innovative performance are investigated. These concepts were previously only researched for the regular innovative performance context.

In addition to this scientific relevance there is also a practical relevance to this research. This research could be helpful for companies generating environmental innovations that lie outside their core business. The results will answer questions such as: Will we need many partners? Will these have to be different types of partners? How many times should we interact? In what way should we interact? Moreover, helping companies with these issues can increase their environmental innovative performance and in turn better our chances of achieving a sustainable society.

This report is structured as follows. The next chapter provides an overview of the underlying theoretical framework that is used in this research and the hypotheses that are tested. After that, the method section goes into the research design, research context, sampling strategy, data collection, data analysis, and the quality indicators. The following section provides descriptives, correlations, and findings of the regression analyses, and the hypotheses are confirmed or rejected. Then, the conclusions of this research are given and an extensive discussion is provided on the results, implications and limitations. Finally, the references and appendices are provided.

Theory

This section of the research goes into the theory behind the concepts. Previous research and definitions are discussed and hypotheses in the context of this research are stated. First, the dependent variable of environmental innovative performance is addressed, after which the independent variables and moderator are discussed. Finally, a conceptual model is provided that represents the concepts and their relations.

Environmental Innovative Performance

Innovation is a concept that can be defined in different ways. Rogers (2003, p. 11) defines it as 'an idea, a practice or an object that is perceived as new by an individual or other unit of adoption'. This thus covers all kinds of innovations as long as it is new for the innovating organization. Other well-known authors of innovation literature have an extended definition in that it entails successfully bringing inventions to the market (Utterback, 1996; Porter, 2011). In this case, it is not only about inventing something new, but also being able to exploit the invention (Roberts, 1988; Afuah, 2003; Rogers, 2003). A distinction is often made between product and process innovation. Product innovations can be new products or services, but also improvements on existing products or services (Utterback, 1996; Porter, 2011). Process innovations are changes in the way these products and services are developed. Thus, improved or new production processes (Utterback, 1996; Porter, 2011).

Environmental innovation is seen as a specific type of innovation. It is not only about novel or improved products and processes but also about the impact that they have on the environment. Environmental innovation is defined by Beise & Rennings (2005, p. 6) as: 'new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harms'. For instance, changes in products or production processes can be focused on emission reduction, waste management, recycling, materials and energy use etc. (De Marchi, 2012). The distinction between product and process innovation can be made in the same way for environmental innovation. These environmental innovations are considered to be technological innovations as defined by OECD (2002). This, thus, does not include organizational innovations. Because little research is done that takes into account the differences between environmental product and process innovation (Rennings, et al., 2006; Hellström, 2007), these are both included in the research in order to identify possible differences in characteristics and relations. Furthermore, there are two ways in which companies can be involved in the innovation process. The first is actual generation of the innovation, which means that the company is actively involved in idea generation, development and commercialization of a product or process innovation. The second is the adoption of innovations that are generated by others, which deals with searching, selecting and implementing that innovation (Damanpour & Gopalakrishnan, 1998; Damanpour & Wischnevsky, 2006). Finally, this research focuses on the generation of environmental innovations because it deals closely with companies working far from their own traditional knowledge base which is the problem described in the introduction above.

As discussed in the introduction, there are two essential ways in which environmental innovation differs from regular innovation. These differences are important to fully comprehend the different context of this type of innovation. Much research already exists on the double externality problem and drivers for environmental innovation. The second difference with regular innovation focuses on the aspect that for most companies environmental innovations do not lie in their core business. This means that often they do not possess the knowledge or resources needed to produce these innovations or implement them in their processes (Chappin, 2008; De Marchi, 2012). Environmental innovation, same as regular innovation, cannot take place in isolation due to its nature. Environmental innovation is often more systemic, complex and multidisciplinary than regular innovation and takes companies further away from their own traditional knowledge base (De Marchi, 2012). Consequently, this takes them to interacting with companies that are new to them and have a different knowledge base (De Marchi & Grandinetti, 2013) as well as interacting more with their own network partners (De Marchi, 2012). Environmental innovation is often concerned with making changes in design, quality, raw materials used, and energy efficiency which requires collaboration with external partners (Lefebvre et al., 2003). For instance, for a company to be able to state that their products or processes are 'green' it is important to ensure that the components from suppliers are also 'green'. Relations with suppliers, clients and other actors thus become increasingly important to ensure environmental-friendly features as well as knowledge and skills to generate the environmental innovations (De Marchi, 2012).

The focus of this research lies on the environmental innovative performance of companies. This concept can be defined in different ways. As proposed by Hagedoorn and Cloodt (2003) innovative performance can be seen as the rate with which companies introduce new products or processes to the market. For environmental innovation the same definition could then be used including the aspect that these products and processes are avoiding or reducing environmental harm. However, considering the fundamental differences between regular innovation and environmental innovation a more nuanced definition is chosen in this research that emphasizes more explicit aspects. As stated by Lefebvre et al. (2003) a comprehensive perspective has to be taken that looks at the extent to which a company has taken explicit action to account for environmental aspects in the products and processes that it generates. This entails all activities from product design to product disposal. Additionally, Lefebvre et al. (2003) include two more dimensions in the definition of environmental innovative performance of companies: an organizational dimension that focuses on management systems and a financial dimension that measures the environmental R&D input. In this research the dependent variable is defined only by the first dimension explained here: the extent to which a company has taken into account environmental aspects in the generation of their products and processes. The organizational dimension is not addressed because this research only focuses on technological innovation, not on organizational innovation. The financial measure of R&D investments is not chosen as the dependent variable due to criticism about its ability to depict innovative performance as it is only an economic input measure (Evangelista et al., 1998; Smith, 2005). As is discussed in the next chapter, additional dimensions, such as the generation of new products and processes and R&D input, are included as alternative measures for environmental innovative performance to ensure robustness of the dependent variable.

Network Characteristics

As discussed above, the complexity and multidisciplinarity of environmental innovation leads organizations to collaborate with others. They are in need of networks to gain the knowledge that is required. Network characteristics that are often presented in literature are network size (Teece, 1986; Schilling & Phelps, 2007; De Marchi, 2012), clustering and reach (Schilling & Phelps, 2007), inter-firm interdependence (Grandori & Soda, 1995), and heterogeneity of partners (Rodan & Galunic, 2004; Nieto & Santamaria, 2007; Fritsch & Kauffeld-Monz, 2010; Oerlemans et al., 2013). This research looks only at the network size and heterogeneity of partners in the form of cognitive diversity. These two characteristics lie closer to the issue of collaborating for knowledge that lies far from the core business of companies. Furthermore, the other aspects focus more on a higher analysis levels and more social perspectives.

First, the network size is important as literature has indicated that having more partners provides more opportunities for companies to collect the complementary knowledge that they need (Teece, 1986). Other companies could have better access to and be more familiar with the knowledge involved in an innovation (Schilling & Phelps, 2007). An increase in network size would thus result in higher innovative performance. However, at a certain point having more partners does not have the same effect on innovative performance because the additional benefits decrease (Deeds & Hill, 1996). New partners could provide knowledge that a company already has obtained through another collaboration (Gomes-Casseres, 1994; Burt, 2009). Besides the knowledge that is gained, efforts to coordinate and screen all collaborations increase when the network grows. Collaborating with more organizations becomes harder and harder to a point where an increase in network size is detrimental to the innovative performance (Gilsing et al., 2008; Rothaermel & Alexandre, 2009; Faems et al., 2012). After a certain point, the innovative performance thus decreases when the network gets larger.

In EI it is also important to collaborate with partners that have complementary knowledge as they are confronted with knowledge further away from their own traditional knowledge base (Chappin, 2008; De Marchi, 2012). Thus, more partners would results in higher environmental innovative performance. Furthermore, dealing with complex knowledge also results in high coordination efforts that have a negative effect on the environmental innovative performance. Therefore, the relation between network size and environmental innovative performance is also expected to have an inverted u-shape (see figure 1). This relation is expected to be the same for environmental product and process innovations. Both product and process innovation require networks to obtain knowledge, therefore an increase in network size would be beneficial for both types. Furthermore, both types of environmental innovation can be influenced by coordination problems, and therefore both would encounter negative returns if network size keeps increasing. This leads to the following hypotheses:

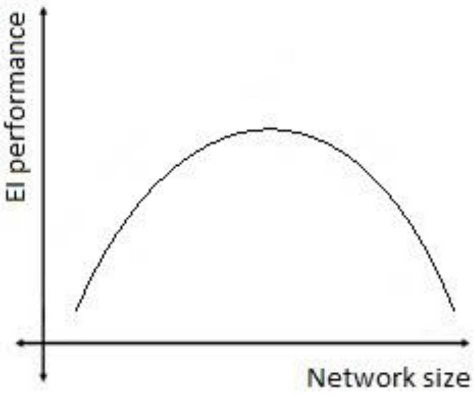


Figure 1, inverted u-shape relation between network size and EI performance

H1a: Network size has an inverted U-shaped relation with environmental product innovative performance.

H1b: Network size has an inverted U-shaped relation with environmental process innovative performance.

Next, it is not only important to look at the size of the network but also at the type of companies that are in that network. Research on the dyadic relations between companies have shown the relevance of aspects such as their geographical, organizational, institutional, social and cognitive proximity to the focal company(Boschma, 2005 Nooteboom et al., 2007). For this research it is most interesting to look at the cognitive proximity, because companies in EI are faced with problems that require different types of knowledge, that lie far from their own knowledge base (Chappin, 2008; De Marchi, 2012). Cognitive proximity, as described by Boschma (2005) and Nooteboom et al. (2007), deals with the distance between companies' knowledge and reference space. Literature shows thatneither being too close nor too far apart is good for exchanging knowledge. If two companies have very similar knowledge, they will not be able to gain much novel knowledge from each other. On the other hand, if their knowledge is too different, they will not be able to understand each other. This means that there is an optimal point where companies can benefit most from each other's knowledge (Boschma, 2005; Nooteboom et al., 2007). This cognitive aspect thus influences the ability of a company to obtain the knowledge needed for their innovations.

When companies are dealing with environmental innovation, they are in need of different types of knowledge due to its complex and multidisciplinary nature. This research therefore does not focus on the dyadic relationship between companies but the variety of types of partners within the entire network of a company. For regular innovation heterogeneity of actors is already argued by many as being necessary to maintain novelty of knowledge (Rodan & Galunic, 2004; Nieto & Santamaria, 2007; Fritsch & Kauffeld-Monz, 2010; Oerlemans et al., 2013). For example, customers can provide insights into specific demands and needs (Von Hippel, 1986; Lundvall, 2010), and many innovations that require complex knowledge have their origins in research institutes and universities (Powell, 1996). After a certain amount of diversity, additional diversity will not be as beneficial anymore as companies are not able to cope with too many different types of knowledge at the same time. Also, as discussed by Goerzen & Beamish (2005), when the diversity of a network keeps increasing, benefits are harder to appropriate and management becomes more difficult. For companies the problem is often not acquiring diverse knowledge but integrating it into the company (Mors, 2010) and coordinating (Duysters et al., 2012). However, contrary to the situation for network size, an increase in diversity is not expected to have a negative effect on the innovative performance. Additional diversity means that there is still novel knowledge presented (Rodan & Galunic, 2004; Nieto & Santamaria, 2007; Fritsch & Kauffeld-Monz, 2010), whereas as increased network size after a point does not add any novel knowledge (Gomes-Casseres, 1994; Burt, 2009). Therefore, a maximum innovative performance is expected to be reached, with the positive effects of additional knowledge weighing against the negative effects of coordination and integration efforts.

For environmental innovation this relation is expected to be the same (see figure 2). First, higher levels of diversity are also expected to result in higher EI performance, due to the need for diverse knowledge in EI. However, after a certain point, coordination and integration issues with diverse knowledge will also be present for companies in EI. Cognitive diversity within the network is found by literature to be relevant for product innovations (Nieto & Santamaría, 2007), and the same is argued here for process innovations. The hypotheses are:

H2a: Cognitive diversity is positively related with diminishing returns to environmental product innovative performance.

H2b: Cognitive diversity is positively related with diminishing returns to environmental process innovative performance.

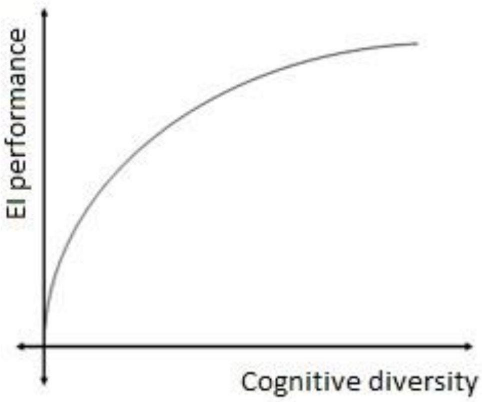


Figure 2, diminishing returns for relation between cognitive diversity and EI performance

Absorptive Capacity

As discussed above, it is not only important that companies are able to gather novel knowledge but also that they are able to coordinate and integrate the knowledge. Cohen and Levinthal (1990) argue that the ability to exploit external knowledge is crucial in innovation and that this is dependent on prior knowledge. This ability to "*recognize the value of new, external information, assimilate it, and apply it to commercial ends"* is what they call absorptive capacity (Cohen & Levinthal, 1990; p1). Prior knowledge can mean that companies have basic skills and understanding of the subject, which makes it easier for them to use external knowledge (Cohen & Levinthal, 1990; Veugelers, 1997). For companies in EI it is hard to internalize the external knowledge due to differences in knowledge base, and therefore absorptive capacity is an important concept to take into account (Gluch et al., 2009).

For companies to benefit from their network they must be able to absorb the knowledge that the network offers (Tsai, 2001). Thus, absorptive capacity plays an important role in this relation as companies with a higher absorptive capacity are better able to absorb novel knowledge (Cohen & Levinthal, 1990). This in turn results in higher innovative performance as companies benefit more from their networks. This is expected to have the same effect for environmental innovation as it is important for those companies to benefit from the knowledge in their networks in order to perform (Chappin, 2008; De Marchi, 2012). Therefore, absorptive capacity is expected to have a positive moderating effect on the relation between network size and environmental innovative performance (see figure 3). Firstly, they will be able to benefit more from less network partners as can be seen by the steeper curve. Secondly, they will be able to reach a higher EI performance than companies with low absorptive capacity. Finally, they will be able to gain more from large networks.. The effect is expected to be the same for both product and process innovations as they are both concerned with recognizing, assimilating and applying new knowledge (Zahra & George, 2002). This leads to the following hypotheses:

H3a: The level of absorptive capacity has a positive moderating effect on the relation between network size and environmental product innovative performance.

H3b: The level of absorptive capacity has a positive moderating effect on the relation between network size and environmental process innovative performance.

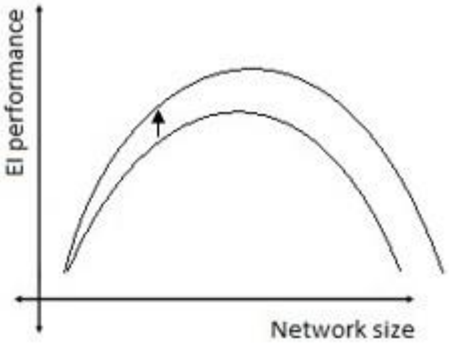


Figure 3, moderating effect of absorptive capacity on relation between network size and EI performance

Absorptive capacity is also expected to have a moderating effect on the relation between cognitive diversity and EI performance. Again, the ability to absorb knowledge that the company wants to gain is instrumental in benefitting from a network (Tsai, 2001). In this case, EI is concerned with a diverse network and different types of knowledge that need to be internalized in order to increase EI performance. Having a large absorptive capacity is then beneficial. A company that is better able at processing the highly diverse knowledge will be better at using a cognitive diversity within a network to generate environmental innovations and thus perform better. This means that companies will be able to get a higher environmental innovative performance with the same amount of cognitive diversity. Also, companies with higher absorptive capacity are expected to be able to handle higher levels of diversity and thus have higher potential EI performance (the relation evens out later). This relation is shown in figure 4. This effect is again expected to be the same for both product and process innovation as recognizing, assimilating and applying new knowledge is essential for both types of innovation (Zahra & George, 2002). The hypotheses are:

H4a: The level of absorptive capacity has a positive moderating effect on the relation between cognitive diversity and environmental product innovative performance.

H4b: The level of absorptive capacity has a positive moderating effect on the relation between cognitive diversity and environmental process innovative performance.

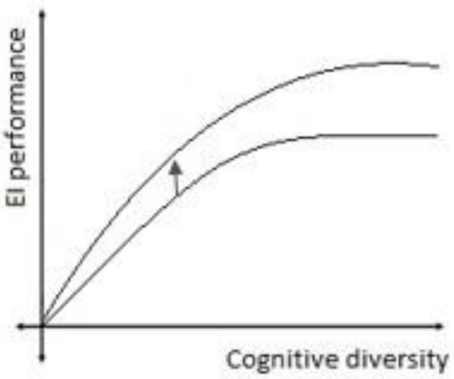


Figure 4, moderating effect of absorptive capacity on relation between cognitive diversity and EI performance

Interaction Characteristics

Besides having a network that is large and diverse enough for environmental innovation, it is also important to interact in a beneficial way with that network (Ebadi & Utterback, 1984; Mohr et al., 1996). This research therefore also looks at the interaction characteristics of companies involved in environmental innovation. Literature indicates several aspects that can be relevant for interaction, such as: frequency of interaction, formality and informality of interaction (Mohr & Nevin, 1990; Morand, 1995; Lorenzoni & Lipparini, 1999; Cavusgil et al., 2003; Lavie, 2006; Capaldo, 2007), levels of trust (Sako, 1992; Das & Teng, 1998), conflict management (Park & Unsong, 2001), types of communication, bargaining, and influence tactics (Frazier & Rody, 1991; Young & Wilkinson, 1998). This research looks at the first three aspects mentioned here as they are considered to be the most important by a large amount of literature.

The frequency of interaction deals with how often a company interacts with another actor in order to gain knowledge. Literature shows that higher frequency of interaction is conducive of higher levels of innovative performance (Czepiel, 1975; Ebadi & Utterback, 1984; Ahuja, 2000; Cavusgil et al., 2003) More frequent interaction builds stronger relationships in which mutual trust can develop (Gulati, 1998; Capaldo, 2007). Furthermore, increasing the frequency of interaction provides a resource commitment and makes reciprocity an unwritten rule (Capaldo, 2007). . In innovation, as in environmental innovation, knowledge is complex and a company cannot simply learn everything in the first interaction. Thus, a higher interaction frequency is expected to result in higher environmental innovative performance. This relation is expected to be the same for product and process innovation as both rely on complex knowledge. This leads to the following hypotheses:

H5a: A higher frequency of interaction leads to a higher environmental product innovative performance.

H5b: A higher frequency of interaction leads to a higher environmental process innovative performance.

Besides looking at the interaction frequency this research also takes into account the formality of interaction. The degree of formality of an interaction that is used in this research is based on the definition by Ruekert and Walker (1987; p6) *'the degree to which rules or standard operating procedures are used to govern the interaction between two individuals in different functional areas'.* In this research this degree is measured between two partners in an inter-firm relationship. Literature states that formality of interaction has a positive influence on innovative performance (Moenaert et al., 1994). Higher levels of formality are argued to increase the efficiency of repetitive interaction and decrease uncertainty and ambiguity (Ruekert & Walker, 1987). When interaction becomes more efficient and uncertainty is reduced, it can result in higher innovative performance. For environmental innovation this efficiency in interacting with partners for complex knowledge is also important. Moreover, EI is associated with high levels of uncertainty and therefore formal interaction is expected to be beneficial for environmental innovative performance. In conclusion, higher levels of formality thus result in higher environmental innovative performance. This relation is expected to be the same for product and process innovation as both types deal with uncertainty in interactions. The hypotheses are as follows:

H6a: Higher levels of formality lead to higher environmental product innovative performance.

H6b: Higher levels of formality lead to higher environmental process innovative performance.

Apart from formality of interaction, literature often also looks at informal interaction (Nadler & Tushman, 1989; Griffin & Hauser, 1996; Zahra & Nielsen, 2002). Whereas formal interaction goes through the official channels and is associated with rules and procedures, informal interaction works outside the formal boundaries of the company (Griffin & Hauser, 1996). It is also more often associated with a face-to-face approach (Moenaert et al., 1994) or the use of social or electronic media (Leenders et al., 2003). As these are two different types of interaction, formal and informal interaction are taken in this research as two separate notions, not two sides of the same scale. Formal and informal interaction can exist simultaneously. Informal interaction plays an important role in stimulating creativity (Rothwell et al., 1974), which is necessary for innovation and also for environmental innovation. Furthermore, informality is argued to result in more openness, which is beneficial for the innovative performance of companies (Bascavusogly-Moreau et al., 2013). Moreover, literature states that informal interaction is conducive of more and more effective interaction (Camelo-Ordaz et al., 2005). Informal interaction is often used to build exchange relations in which reciprocity of knowledge is essential (Von Hippel, 1989). However, once the value of knowledge is deemed highly valuable informal interaction is no longer used due to risk perception of information leakage (Mansfield, 1985; Von Hippel, 1989). For environmental innovative performance it is important to be creative in finding solutions and combining different types of knowledge due to its multidisciplinarity. Therefore, higher levels of informality are argued to result in higher EI performance. This relation is expected to be the same for product and process, as these are both multidisciplinary. The hypotheses are:

H7a: Higher levels of informality lead to higher environmental product innovative performance.

H7b: Higher levels of informality lead to higher environmental process innovative performance.

Conceptual Model

The conceptual model in figure 5 below shows the relations between the concepts as discussed above.

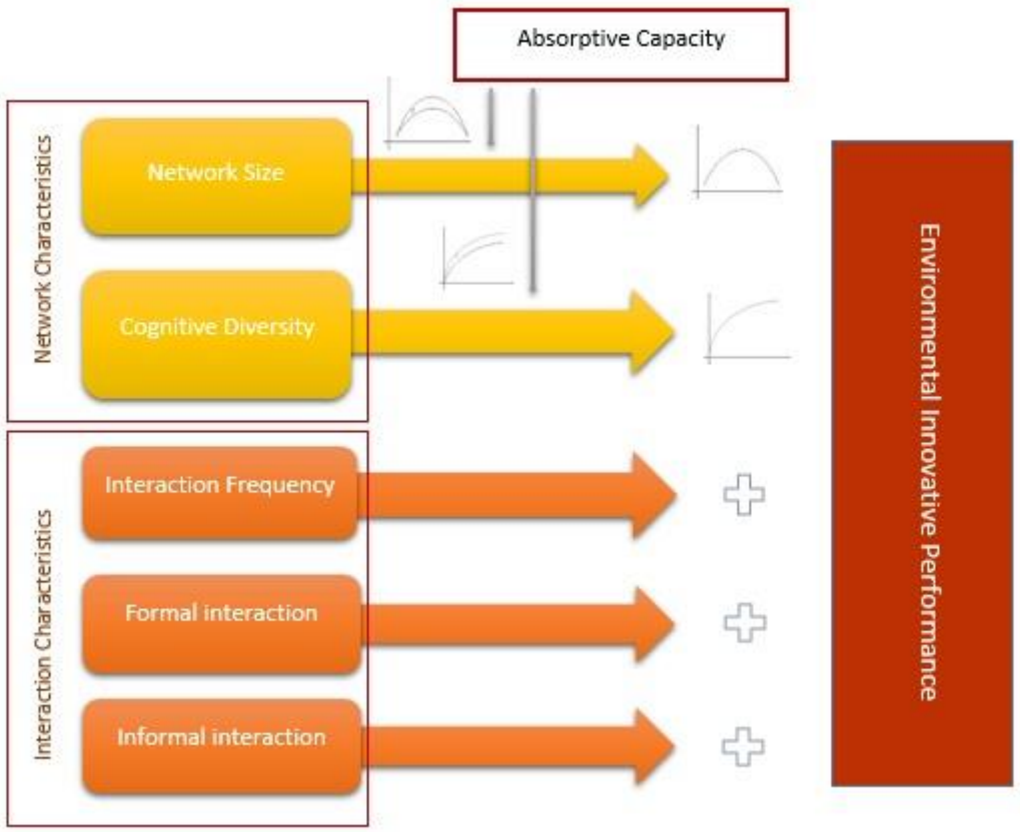


Figure 5) Conceptual model

Methods

This section provides an overview of the methods used in this research. First, the overall design is presented and research context, sampling and data collection are discussed. After that, the use of measures and the data analysis are explained. Finally, an account of the quality indicators of the research is given.

Research Design

The aim of this research was to investigate the relation between the network and interaction characteristics and EI performance. A quantitative approach was chosen as this fits best with the deductive nature of this research. A cross-sectional design was used to provide a quantitative answer by collecting data on multiple cases at one point in time (Bryman, 2008). The cross-sectional design is suitable for descriptive analysis such as in this research (Punch, 2013).. This is also the most practical design, as a longitudinal design is not feasible in light of time and monetary constraints (Bryman, 2008; Punch, 2013). The units of analysis for this research are organizations within the technological industry. The units of observation within these organizations are managers or R&D employees.

Empirical Context

This research targets the population of manufacturing organizations within the technology industry in The Netherlands. Most of these organizations are covered by the branch organizations of FME (Federatie voor de Metaal en Elektrotechnische Industrie) en FHI (Federatie Het Instrument). Together they account for over 3000 companies in this industry, which is about 70% of the total amount of companies in this industry in the Netherlands (FME, 2014; FHI, 2014; CBS, 2014a). These companies consist of different sizes, ages, interests and innovation focus and there is no reason to assume there would be any issues with the representativeness of this sample. FME is an organization for entrepreneurs in the Dutch technology industry and aims to connect members to overcome challenges (FME, 2014). FHI is the federation for technology branches in The Netherlands and serves as an umbrella corporation for several sectors: industrial automation, industrial electronics, laboratory technology and medical technology (FHI, 2014). The technology industry of The Netherlands provides a good context for this research. Firstly, due to its technological focus this is a suitable context to investigate technological innovation. Moreover, this industry deals with both product and process innovations. Thirdly, this industry has increased its focus on sustainability issues the past couple of years. There is more attention for declining gas resources in The Netherlands, raw materials supply and usage (FME, 2012) as well as pollution and waste management and energy use (FHI, 2008; 2013). The Dutch industry has improved its numbers with regard to environmental issues as can be seen in table 1 (CBS, 2014b).

Table 1) Environmental statistics Dutch industry (CBS, 2014b)

	1995	**2000**	**2005**	**2010**	**2012***
Energy Use (PJ)	1 205	1 274	1 422	1 451	1 411
Use tab water (mln m3)	-	-	154,4	147,0	-
Waste (mln kg)	-	-	15 699	14 053	-
Heavy metals to water (1000 equivalents)	31	15	11	7	-
Nutrients to water (1000 equivalents)	6 703	4 266	2 984	1 907	-

Climate Change (mln GHG equivalents)	62 612	57 320	53 320	46 738	45 118
Acidification (bln acid-equivalents)	4,8	2,7	2,6	1,7	1,8
Ozone layer degradation (1000 CFK12-equivalents)	373,3	41,9	0,0	0,0	0,0
Particles (mln kg)	21,7	12,9	9,9	8,0	7,5

*preliminary data

This table shows that the amount of energy consumption has increased while the water use, waste, metals, nutrients, greenhouse gases, acids, and particles has decreased in the period of 1995 to 2012. The amount of ozone layer degradation that this industry used to cause has even been completely eliminated (CBS, 2014b).

Data Collection and Sampling Strategy

In order to collect the data necessary for the quantitative analysis online self-completion questionnaires were used. Questionnaires are a good and easy way to ensure reaching many respondents that may be geographically dispersed. Also, the answers that people give are not influenced by a researcher that is present at that point (Bryman, 2008; Punch, 2013). In this case, using online questionnaires was the best way to ensure reaching many respondents within a limited timeframe. The questionnaires consist of closed questions, such as 'yes or no' questions and Likert scales to keep the questionnaires as simple and clear as possible as well as provide useful data for the quantitative analysis. The concepts were measured on existing scales if possible.

Before sending out the questionnaires a pilot test was conducted. The concept version was sent to several people, some within the same field of interest, others completely outside of this field. Their feedback was used to adjust the questionnaires when necessary. Mostly, small adjustments were made regarding formulation of questions and length of the questionnaires. The website www.thesistools.com was used to build and distribute the questionnaires (for an example of the questionnaire see Appendix IV).

After the final corrections the questionnaire was sent through emails to the companies of the sample. Using the websites of the branch organizations the companies that fit in the sample were selected. The contact information of these companies were found either on the branch organization websites or their own personal websites. The email that was sent contained an invitation to participate in the research with a short explanation of the research and its importance (see Appendix III). The email also provided a link to the online questionnaire and an overview of what to expect. Finally, the contact person was asked to make sure that the questionnaire was filled in by an employee in a management position or an R&D employee. This was done to ensure that the questionnaires were answered by people with sufficient knowledge on the subject as well as information about the company itself. Reminder emails were sent after two weeks and again after another week to increase response rates. The reminders placed extra emphasis on the importance of their participation and the value of the research.

In total, 1902 companies were targeted that are in the technological industry in the Netherlands. Some of the email contacts on the websites were old, some companies were no longer active in the industry and some simply did not provide any contact information. In the end, 1794 companies were reached: 613 from branch organization FHI and 1181 from FME (see table 2 below). In Thesis tools 65 questionnaires were received for FHI and 112 for FME of which respectively 24 and 63 were useful. This concluded in a database of 87 useable answers. Many of the received questionnaires that could not be used for analysis were (almost completely) empty. In email responses and the comments option of the questionnaire itself some of these companies indicated that they were not able to answer the questions because they are not manufacturing companies but only do sales. Others indicated that this questionnaire was not applicable to them. These issues with data collection and nonresponse are discussed further in the discussion section and Appendix I.

Table 2) Response rates

	Sent	Reached	Received	Completed	Effective response rate
FHI	675	613	65	24	3.9%
FME	1227	1181	112	63	5.3%
Total	1902	1794	177	87	4.8%

Operationalization

The concepts that are measured in this research are operationalized here and an extensive operationalization table is provided in Appendix II. These concepts include the dependent variable(s), the independent variables, the moderator, and control variables, the latter to ensure the relations are not influenced by other factors.

Dependent Variable

Environmental innovative performance is measured as the environmental performance of companies, based on eight items as set by Hemmelskamp (1999) and Lefebvre et al. (2003). For product innovation this is measured through self-evaluation of developing new environmentally-friendly products, improving design, improving product quality and product security. For process innovation this is measured through self-evaluation of efficiency of manufacturing, cost reductions due to raw materials, decreasing energy consumption, and improvement of working conditions (Hemmelskamp, 1999; Lefebvre et al., 2003). According to Lefebvre et al. (2003) the items for product innovation score a Cronbach's Alpha of 0.96 and those for process innovation a Cronbach's Alpha of 0.90. All of these are items measured on a 5-point Likert scale (see Appendix II). To ensure these items could be used in this research to measure the variables (4 items for product innovation and 4 items for process innovation) a factor analysis was executed.

The factor analysis for environmental product innovative performance provided a KMO of 0,755 and Bartlett's Test of Sphericity was significant (,000). The scree plot (see appendix V) as well as the total variance explained indicated that these items can be taken within one factor. After the factor analysis, a reliability analysis was conducted. The results are shown in table 3. The Cronbach's Alpha from the reliability analysis was ,784. Scores over ,7 are considered reliable and therefore these items can be used together (by taking the average) to measure the environmental product innovative performance.

Table 3) Factor Analysis and Reliability Analysis Environmental product innovative performance

Item	Mean	SD	Item Loadings	% Total Variance Explained	Cronbach's Alpha if item deleted	Cronbach's Alpha Total
New EI Products	3,76	1,007	,750		,753	
Improvements in Design	3,59	,748	,740		,760	

Improvements in Quality	3,77	,906	,874		,660	
Improvements in Security	3,08	1,031	,769		,743	
Total				61,616		,784

The factor analysis for environmental process innovative performance provided a KMO of 0,473 and Bartlett's Test of Sphericity was significant (,000). The KMO score was lower than ,6 which indicated possible problems with reliability. The scree plot (see appendix V) as well as the total variance explained indicated that these items cannot be taken within one factor but rather two. Also the reliability analysis indicated the same with a Cronbach's Alpha of ,582. This score is lower than the accepted value of ,7 and therefore these items cannot be taken within one factor.

Table 4) Reliability Analysis environmental process innovative performance (4 items)

	Cronbach's Alpha if item deleted
Improvements in working conditions	,444
Cost reductions energy	,460
Cost reductions raw materials	,491
Improvements efficiency	,610

The Cronbach's Alpha if item deleted indicated that the item of efficiency should be measured separately (see Table 4). A separate measure is thus used for environmental process (efficiency) innovative performance and another separate measure for the other three items (average). The results of the factor analysis and reliability analysis for these three items are shown in table 5.

Table 5) Factor Analysis and Reliability Analysis Environment process innovative performance (3 items)

Item	Mean	SD	Item Loadings	% Total Variance Explained	Cronbach's Alpha if item deleted	Cronbach's Alpha
Improvements in working conditions	3,23	1,108	,599		,680	
Cost reductions energy	3,21	,986	,849		,324	
Cost reductions raw materials	3,28	1,172	,790		,480	
Total				56,792		,610

The Cronbach's Alpha is now more acceptable, but still not above the threshold value of ,7. The total variance explained is sufficient. The measure focusing on efficiency improvements is now named EI process I and the three combined items are named process II.

Alternative Measures

Another way to measure the environmental innovative performance is by looking at the percentage of environmental product and process innovations a company has generated compared to their total amount of products and processes. This measurement of the amount of generated environmental product and process innovations (Hagedoorn & Cloodt, 2003) is labelled as the quantitative performance.

A third way to measure the performance is by looking at the financial gains that come from the generation of the environmental innovations. For product innovations, this is measured by taking the percentage of revenue that is produced by the environmental innovations, as used by Laursen and Salter (2006). For process innovations this is measured with a percentage of expenditures saved by EI. This performance measure is called the financial performance.

These two alternative measures are used in this research to perform a robustness check on the dependent variable.

Independent variables

Network size is measured through the number of partners a company has for environmental innovation (Schilling & Phelps, 2007).

Cognitive diversity is measured by a diversity index, which measures the different types of partners that a company has and the distribution between these types. These different types are based on the knowledge that these partners have. This research takes into account: universities, public research institutes, commercial labs, governmental institutions, industry associations, suppliers, customers, consultancies and competitors as in Oerlemans et al. (2013). The diversity was then calculated through the use of the Blau index formula: $1\text{-}\Sigma PK^2$, in which P is the proportion of partner type in K the network. Scores between 0 (low diversity) and 1 (high diversity) came out of this calculation (Duysters & Lokshin, 2011; Oerlemans et al., 2013). The data showed some problems with expressing the diversity through this index. The scores were affected by high peaks for some organization types. Therefore, this research uses the number of different types of partners as a measure for cognitive diversity in order to deal with this distribution bias. See table 6 below for an example in which high peaks influence the diversity index score of a respondent. This example shows how one company scores rather low on the diversity index while it does collaborate with 8 different partners and has overall higher numbers of partners. Due to the score of 300 for collaborating with customers, this respondent scores a lot lower than expected. As can be seen in the table the less diverse company scores higher on the diversity index.

Table 6) example distribution bias cognitive diversity

	Uni	PRI	CL	GI	IA	Sup	Cust	Cons	Comp	**Diversity Index**	**Different partners**
Respondent 3	0	1	0	2	1	2	1	0	0	,78	5
Respondent 10	4	20	6	10	1	20	300	1	0	,31	8

Interaction frequency is measured by the number of interactions the company has with its partners (Mohr et al., 1996). Frequency is measured on two scales: one scale daily-weekly-monthly-3 monthly-yearly, and the other rarely-often. The data show that scores on both scales are similar without any outliers. As the interaction frequency is measured on two different scales these cannot be combined easily. Therefore, this research uses the scale from daily to yearly to measure the frequency. The scale is reversed to make sure that the frequency runs from low to high.

Degree of formality is measured through four items, as provided by Ruekert and Walker (1987). They measured formality in terms of the relationship being discussed (1) and documented (2), standard operating procedures being set in place (3) and formal channels of communication being followed (4). In order to see if these items can be measured under the same variable a factor analysis is done. The KMO score is ,798 and Bartlett's test of sphericity is significant (,000). As can be seen in table 7 below, the reliability analysis provides a Cronbach's Alpha of ,886. These items were thus taken together and averaged into one variable for formality.

Table 7) Factor analysis and reliability analysis Degree of formality

Item	Mean	SD	Item Loadings component	% Total Variance Explained	Cronbach's Alpha if item deleted	Cronbach's Alpha
Discuss terms	3,49	1,142	,907	74,642	,827	,886
Document terms	2,93	1,271	,898		,834	
SOP	2,96	1,206	,876		,846	
Formal channels	3,30	1,095	,767		,898	

To measure the degree of informality this research used a separate variable that is measured by the extent to which informal channels of communication are followed. The informality is thus not measured on the same scale as formality, as these two types of interaction can exist simultaneously (Tushman & Scanlan, 1981).

Moderator variable

There are two ways in which absorptive capacity is usually measured by scholars. Originally and typically, it is measured by R&D intensity, which entails R&D expenditures divided by total sales (Cohen & Levinthal, 1990; Tsai, 2001). However, the past years this measurement has been criticized by many scholars for being incomplete. Several argue that absorptive capacity has four different dimensions: acquisition, assimilation, transformation and exploitation, each with its own indicators (Zahra & George, 2002; Camisón & Forés, 2010; Liu et al., 2013). Though the latter measure would have been preferred, this research uses the measurement of R&D intensity because of constraints in the length of the online questionnaires. This measure is still recognized as a good measure by a large amount of literature and can provide valuable insights. The R&D intensity was measured for the year 2011 and the year 2013 and then averaged to provide the measure for absorptive capacity.

Control variables

To make sure the independent and dependent variables from the conceptual model are not influenced by other variables, the most relevant control variables are taken into account. Firstly, the size of the company is measured to ensure that, for instance, the environmental innovative performance is not simply different due to size. The company size is measured by the number of employees. Larger companies tend to have more resources (Tsai, 2001), larger networks, and different environmentally focused goals, which makes it easier for them to deal with the complexity and high investment costs of EI (Hemmelskamp, 1999). Large companies often invest more in R&D, produce more patents, and produce more products (Hagedoorn & Cloodt, 2003). The number of employees was measured for the years 2011 and 2013 and then the average was used in the analysis.

Similarly, age of the company is also taken into account through number of years since founding of the company. Older companies can have more resources and larger networks. On the other hand, incumbent companies are often said to be less innovative (Hannan & Freeman, 1984; Huergo &

Jaumandreu, 2004). The companies were asked to fill in the year of foundation of their company, after which this was subtracted from 2013.

Other control variables that are often included in this kind of research are financial performance of companies and the R&D input (Li & Atuahene-Gima, 2001; Hall & Bagchi-Sen, 2002; Hagedoorn & Cloodt, 2003). Companies with higher profits are expected to have more resources which can influence the network characteristics and the innovative performance. Also, companies with higher R&D expenditures are assumed to have higher innovative performance (Hall & Bagchi-Sen, 2002). Considering that this research measures absorptive capacity as the R&D intensity multicollinearity issues were expected and found. Therefore, these two variables are not taken into account separately in this research.

Data Analysis

In order to analyse the data that have been collected the statistics program SPSS is used. The first step in SPSS was to clean the data and check to see if there were any outliers. Unanswered questions as well as 'not applicable' answers were coded as missing values. Network size showed two respondents that scored quite high compared to the other respondents, and were larger and older companies overall. They were not eliminated from the analysis. No extreme outliers were found for any other variables but many variables were not normally distributed. In order to be able to analyse the variables and their relations in an OLS regression it is important to make sure they have normal 'bell-shaped' distribution (Field, 2009; De Vocht, 2009). Consequently, the following step was to transform the variables if necessary, to ensure that they matched the assumptions of the analysis model used.

Network size, absorptive capacity, company size and company age were all positively skewed and therefore logarithmically transformed (Log10(variable)). For histograms with distribution see Appendix V. Cognitive diversity, interaction frequency and degree of (in)formality were normally distributed and did not require a transformation. In order to include the curve-linear relationship as discussed in the hypotheses an additional two variables are computed: network size squared and cognitive diversity squared. Furthermore, the dependent variables for the robustness check (quantitative and financial) show a skewed distribution that cannot be fixed through logarithmic transformation. For these variables the square root was taken of the original variable (SQRT(variable)), see Appendix V. The only exception was the variable of environmental financial product innovative performance, which does not benefit from a transformation. More about these variables is discussed in the robustness check section of the results.

Before going into the regression analysis the variables were checked for multicollinearity issues. This means that two independent variables are highly correlated. This may occur for instance when one variable is constructed by using another. The multicollinearity check provides a VIF (Variance Inflation Factor) that shows if there are any issues with highly correlating variables. A score over 10 is problematic. Usually, scores are either very low or very high. The multicollinearity check shows that several variables were highly correlated and score much higher than 10 and some even had negative VIF values, see table 8 (VIF 1). To solve the issues with multicollinearity the following variables were mean centered as in Stam (2009): absorptive capacity, network size and cognitive diversity. Another multicollinearity check shows that the VIF values have now improved to an acceptable level, see table 8 (VIF 2).

Table 8) multicollinearity check variables

	VIF 1	VIF 2
Company Age	1,323	1,688
Company Size	1,765	1,909
Absorptive Capacity	4,822	4,581
Network Size	.	2,578
Network Size Squared	1,547	2,200
Cognitive Diversity	16,992	3,216
Cognitive Diversity Squared	36,633	1,462
Interaction Frequency	1,711	2,200
Formality	1,433	1,681
Informality	1,264	1,816
Prod. Abs Cap*Network Size	-87,186	6,353
Prod. Abs Cap*Network Size squared	-87,186	4,200
Prod. Abs Cap*Cognitive Diversity	-217,838	4,983
Prod. Abs Cap*Cognitive Diversity squared	15,781	4,346

When all variables have a normal distribution and do not provide any multicollinearity issues the database is ready for the multiple regression analysis. In this case a multiple OLS regression analysis is used, because this investigates the relations between a larger number of independent variables (Field, 2009; De Vocht, 2009). The multiple regression analysis is used to see if there are any significant relations between the independent variables and the dependent variable. The regression analysis is made up of several blocks. The first block contains the control variables (company age and company size) and the moderator (absorptive capacity). The second block contains also the independent variables (network size, network size squared, cognitive diversity, cognitive diversity squared, interaction frequency, formality, informality). The third and final block adds the interaction (or product) terms to the regression to investigate the moderating relationships ("absorptive capacity*network size", "absorptive capacity*network size squared", "absorptive capacity*cognitive diversity", and "absorptive capacity*cognitive diversity squared").

Research Quality indicators

Reliability

The reliability of a research entails the stability of measures over time and the internal reliability of those measures (Bryman, 2008; Field, 2009). In other words, it describes to what extent the results of, for instance, a questionnaire remain the same under different circumstances, given that the rest stays the same (Roberts et al., 2006). In this research a cross-sectional design is chosen, which makes it harder to test for true reliability. As discussed before, a longitudinal design is not feasible considering the time constraints of this research and a re-test of the measures could not be executed. Given the time frame that was chosen for this research (2011-2013) there are no expected influences on this stability, as for instance the economic crisis would around 2008. On the other hand, this research measures the Cronbach's Alpha of the variables to guarantee some level of internal reliability. Most variables scored a sufficient Cronbach's Alpha to ensure this reliability.

Validity

The validity describes the extent to which a concept measures that what it is intended to measure (Bryman & Cramer, 2011). There are several ways of looking at the validity of a research: internal validity, construct validity and external validity (Roberts et al., 2009; Field, 2009). The internal validity deals with the outcomes, the construct validity with the measurement of the concept and the external validity with generalizing the findings (Roberts el al., 2009).

Internal Validity

The internal validity of a research is ensured by taking into account possible other explanations for outcomes (Roberts et al., 2009). The main issue with internal validity for this research is its cross-sectional design which makes it difficult to argue any causal relations. Therefore, the control variables of company age and company size are included to eliminate other influences on the findings. Moreover, a time lag is built into the research by measuring the independent variables over 2011 – 2013, and measuring the dependent variable in 2013. This ensures that the causal relations that are argued are not accidentally the other way around. Also, the causal relations that are stated are grounded in theoretical argumentation based on acknowledged scientific literature.

Construct Validity

The construct validity represents the extent to which a measure actually measures what it is supposed to measure (Bryman, 2008; Roberts et al., 2009). To ensure that the variables are measured correctly this research bases its indicators on previous scientific findings. Moreover, for each concept it is argued why a certain definition or indicator is used and why this is appropriate in this research context. Within the measures themselves sometimes several items are used to measure one concept. A factor analysis is then executed to ensure validity within the measure.

External Validity

The external validity of the research addresses the extent to which findings can be generalized to a larger population (Roberts et al., 2006; Bryman, 2008). In this case, the quantitative nature of the research provides a strong basis for external validity. However, the high levels of non-response as well as not being able to contact all companies within the industry make it harder to generalize the findings to the entire industry (population). Non-response is kept as low as possible by providing simple and clear questionnaires, appealing invitations and several reminders. Also, the final sample that was used in the analysis is expected to be representative for the technological industry in The Netherlands. As can be seen in Appendix I, the data collection process is discussed and an alternative data collection strategy elaborates on improvements in this matter.

Replicability

The replicability of research addresses the extent to which a research can be replicated by another researcher. Thus, it is important to have transparency in the methods of one's research (Bryman, 2008). In this case, the methods of data collection, examples of questionnaires, extensive elaboration on data analysis and all steps involved are provided.

Results

This section of the research interprets the results of the data analysis. First, descriptive statistics of the variables are provided in order gain understanding of the data that are used in the regression analysis. Next, the correlations between the variables are discussed. Then, the outcomes of the regression analyses are discussed and the hypotheses are confirmed or rejected. Finally, several robustness checks are addressed.

Descriptives

Research Context

The average age of the companies in this sample was 34 years. The youngest companies were 1 year old, and the oldest was 108 years old. The average amount of employees in the companies was 487, with an increase between 2011 and 2013. Both sales and R&D expenditures have increased from 2011 to 2013. See table 9.

Table 9) Descriptives research sample

Variable	N	Min	Max	Mean	SD
Company Age	87	1	108	33,87	24,386
Employees 2011	87	1	24 000	476,86	2 706,163
Employees 2013	87	1	25 500	496,93	2 842,146
Sales 2011 (€)	84	150 000	4 500 000 000	100 744 488,1	519 102 018,3
Sales 2013 (€)	84	120 000	4 800 000 000	109 897 103,0	554 816 249,8
R&D 2011 (€)	71	150	30 000 000	1 484 283,80	1 812 988,73
R&D 2013 (€)	71	200	35 000 000	3 909 120,104	4 453 136,031

The companies in this research sample environmentally innovated on average 43% of their products and 24% of their processes. Some companies environmentally innovated all of their products, but none of the company did that for process innovations, see table 10.

Table 10) Descriptives percentage (%) of products and processes environmentally innovated

	N	Min	Max	Mean	SD
Product	73	3	100	43,30	29,135
Process	69	0	60	24,43	17,266

The majority of the respondents in this research were male (52 compared to 6 female). The average age of the respondents was 48,6 with the youngest respondent being 28 and the oldest 72.

Environmental Innovative Performance

The dependent variables are shown in table 11 to have values between 1 and 5 (on Likert scales). On average the companies scored a little above 3, EIP process I (efficiency) scored somewhat higher, around 4. The standard deviations are similar for all three measures, around 0,8.

Table 11) Descriptives dependent variables

Variable	N	Min	Max	Mean	SD
EIP product	73	1,00	4,75	3,5571	,71604
EIP process I	64	1	5	4,02	,826
EIP process II	68	1,00	4,67	3,2279	,81033

Network Size

The average network size was 19,76 with the lowest value being 0 and the highest 362. When looking at these large differences it is found that two companies have scores of 299 and 362, and the rest of the companies have a network size below 55. Taking away these two outliers results in an average network size of about 12. See table 12.

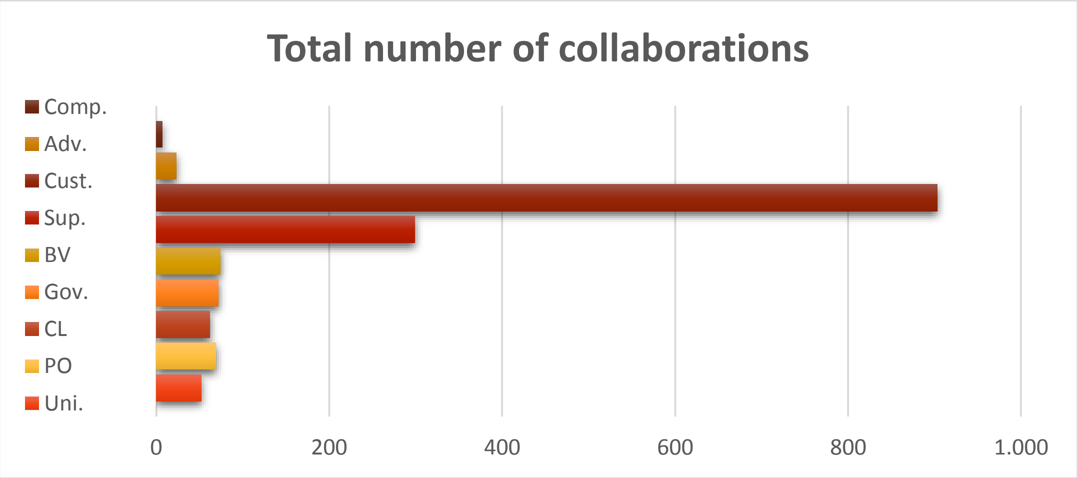
Table 12) Descriptives network size

	N	Min	Max	Mean	SD
Network Size	79	0	362	19,76	51,85
Network Size No Outliers	77	0	54	11,69	11,25

Cognitive Diversity

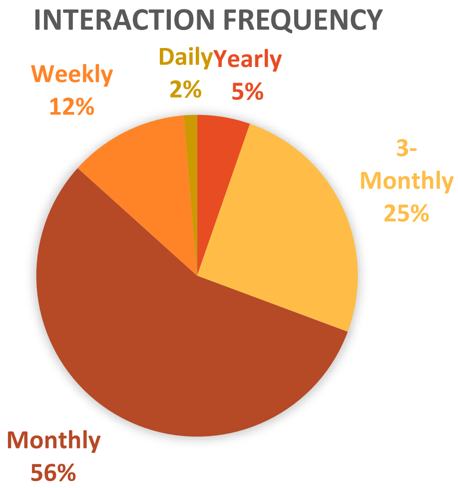
Graph 1 depicts the total number of collaborations per type of organization for all the companies that were in the database. The organization types were: competitors, advisors, customers, suppliers, industry associations, governmental institutions, commercial labs, public research institutes and universities. It is easily visible that most collaborations were with customers and suppliers. The companies were clearly least inclined to work with competitors for environmental innovations. This graph also shows the bias problem for using a diversity index in this research.

Graph 1) Cognitive diversity: total number of collaborations per organization type



Interaction Frequency

As is shown in graph 2, 56% of the companies in this sample interacted on a monthly basis with their partners, which is just above the average interaction frequency of this sample.



Graph 2) Interaction frequency entire sample

Formality

The descriptives of formality are given in table 13.

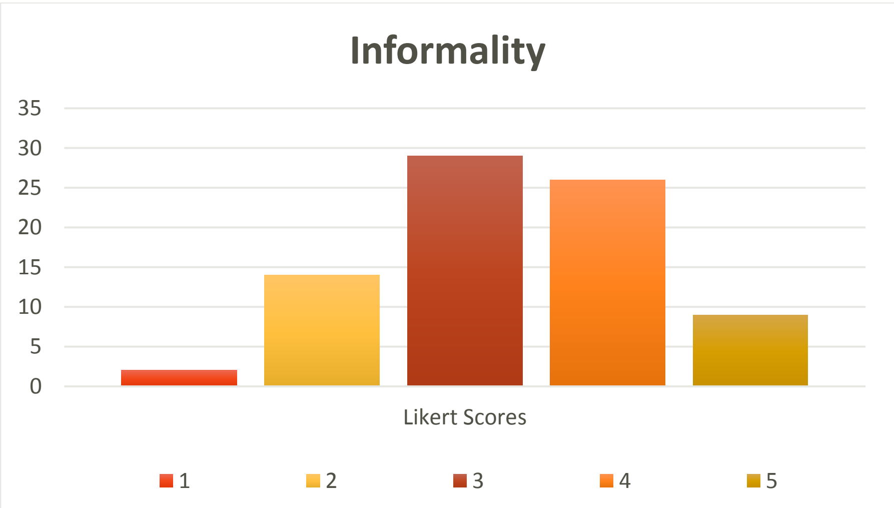
Table 13) Descriptives formality

	N	Min	Max	Mean	SD
Average Formality (4 items)	80	1	5	3,17	1,016

Informality

Graph 3 shows the frequency of the Likert-scores for the variable of informality. The mean of informality is 3,33. The graph illustrates that overall the companies were participating in informal communication with their partners.

Graph 3) Informality distribution



Absorptive Capacity

The absorptive capacity of the companies in this research was ,08679 on average. This means that companies invested 8,7% of their sales in R&D. Looking at the minimum (,003) and maximum values (,800) there is quite some difference. Checking the frequency tables shows that two respondents have much higher absorptive capacities than the rest. Leaving these two respondents out of the analysis, the descriptives show an average of 6,66% with maximum R&D intensities up to 31% (see table 14).

Table 14) Descriptives absorptive capacity

	Min	Max	Mean
2011	0,003175	0,34	0,0661
2013	0,0025	0,28	0,067
Average	0,002917	0,31	0,0666

Final Variables

Table 15 shows the descriptives of the final variables that were used in the multiple regression analysis.

Table 15) Descriptives final variables

Variable	N	Min	Max	Mean	SD
EIP product	73	1,00	4,75	3,5571	,71604
EIP process I	64	1	5	4,02	,826
EIP process II	68	1,00	4,67	3,2279	,81033
Company Age (Log)	87	,00	2,03	1,3959	,38530
Company Size (Log)	87	,00	4,39	1,6192	,77539
Network Size (Log Mean Cent.)	76	-,96	1,60	,0000	,47144
Network Size (Log Mean Cent. Squared)	76	,00	2,56	,2193	,42072
Cognitive Diversity (Mean Cent.	79	-3,35	3,65	,0000	1,78338
Cognitive Diversity (Mean Cent. Squared)	79	,13	13,29	3,1402	3,51967
Interaction Frequency	75	1	5	2,79	,776
Formality	80	1	5	3,17	1,016
Informality	80	1	5	3,33	,978
Absorptive Capacity (Log Mean Cent.)	70	-1,19	1,25	,0000	,51727

Correlations

Table 16 below shows the correlation coefficients between the variables in this research. Values of Pearson's r above ,5 are considered large correlations, meaning they have a strong relationship. Values over ,8 are considered to be problematic (Field, 2009).

As can be seen in the table, the first interesting correlation is that of environmental process innovative performance I and environmental product innovative performance (,506**). These two variables are strongly correlated at a significance level of 0.01. Environmental process innovative performance II is also correlated to Environmental product innovative performance (,454**) at the .01 level of significance. Considering that they all measure environmental innovative performance, and the relations for product and process innovation are assumed to be the same, this is as expected. On the other hand, the two dependent variables for process innovation are not strongly correlated to each other (,117), which is not unexpected as the factor analysis already showed these two could not be measured together.

When looking at the correlations between the independent and dependent variables it can be seen that network size correlates with EIP product (,562**) and with EIP process I (,405**). This indicates that network size and EI performance are positively correlating. Cognitive diversity is correlated to EIP product (,352*) and EIP process II (,343**), which means higher diversity of network partners are associated with higher EI performance. Interaction frequency is associated with EIP product, but the Pearson's r is not very high (,290**). This indicates that a higher frequency of interaction correlates with a higher EI performance for product innovations. Formality is related to both EIP product (,269*) and EIP process II (,313**). The scores are not considered very high but are still significant and indicate that higher levels of formality are associated with higher levels of performance. Informality correlates with both EIP product (-,222*) and EIP process I (-,214*). The negative r scores indicate that higher levels of informality are associated with lower levels of EI performance.

The control variable of company age is correlating with both EIP process I (,294**) and II (,259*). The scores are not very high but still significant. This means that age is a factor that is associated with higher EI performance of companies. Furthermore, company age correlates with company size (,307**) and the product term "absorptive capacity X network size" (,293**). The control variable of company size correlates with EIP product (,249*) and EIP process II (,361**). These scores indicate that larger company size are associated with higher EI performance. Furthermore, company size correlates with network size (,253*), cognitive diversity (,315**), formality (,280**), informality (-,282**), absorptive capacity (-,473**), and "absorptive capacity X cognitive diversity squared" (-,414**). Thus, a larger company size is associated with larger network size, larger cognitive diversity and higher levels of formality. On the other hand, it is also associated with lower levels of informality, lower absorptive capacity and lower moderating effect on cognitive diversity.

Between the independent variables themselves, it is interesting to see cognitive diversity and interaction frequency correlating strongly (,503**). This would mean that higher levels of cognitive diversity are associated with higher frequency of interaction. Cognitive diversity is also related to formality (,293**), with higher levels of cognitive diversity correlating with higher levels of formality. Network size correlates with cognitive diversity (,485**) and interaction frequency (,310**), meaning larger network size is associated with larger cognitive diversity and higher frequency of interaction.

Finally, some correlations can be found between the product terms. The product terms of "absorptive capacity X network size" and "absorptive capacity X cognitive diversity" are strongly correlating (,571**). Also, the network size product term is correlating with the network size squared product term, which is as expected (,385**). Finally, the product squared terms of network size and cognitive diversity are also correlating (,255*). These correlations are as expected because the variables (partly) consist of the same components.

Concluding, the dependent variables are correlating as expected. The independent and dependent variables are partially correlating as would be argued by the theoretical framework of this research.

The control variables are correlating somewhat with several dependent and independent variables, but Pearson's r stays below the threshold of ,5. The few correlations that are found between the independent variables are not alarming either.

Table 16) Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1: DV: EIP product	1																
2: DV: EIP process I	,506**	1															
3: DV: EIP process II	,454**	,117	1														
4: CV Age Company	,167	,294**	,259*	1													
5: CV Size Company (employees)	,249*	,169	,361**	,307**	1												
6: IV Network Size	,562**	,405**	,035	-,052	,253*	1											
7: IV Network Size squared	,171	,140	-,206	-,135	-,051	,364**	1										
8: IV Cognitive Diversity	,352*	,013	,343**	,055	,315**	,485**	-,172	1									
9: IV Cognitive Diversity squared	-,022	,014	,152	-,048	-,066	,078	-,017	-,011	1								
10: IV Interaction Frequency	,290**	,206	,204	,029	,137	,310**	,036	,503**	,020	1							
11: IV Degree of Formality	,269*	,101	,313**	,006	,280**	,177	-,143	,293**	,148	,395**	1						
12: IV Informality	-,222*	-,214*	-,161	,017	-,282**	-,043	-,059	-,020	,002	,138	-,254*	1					
13: Mod. Absorptive Capacity	-,063	-,108	-,168	-,346	-,473**	,159	,046	-,097	,145	-,152	-,144	,157	1				
14: Mod. Absorptive Capacity * Network Size	,032	,175	-,014	,293**	-,059	,011	,357**	-,143	-,106	-,024	-,146	-,057	,030	1			
15: Mod. Absorptive Capacity * Cognitive Diversity	,077	-,064	,004	-,022	-,144	-,082	,065	,168	-,345**	-,037	-,112	-,009	,094	,571**	1		
16. Mod. Absorptive Capacity * Network Size squared	,137	,094	,151	-,085	-,113	,462**	,486**	,052	-,053	-,028	-,168	,151	,479**	,385**	,039	1	
17. Mod. Absorptive Capacity * Cognitive Diversity squared	-,106	-,056	,352	-,021	-,414**	,024	-,031	-,332**	,301**	-,181	-,041	,279*	,632**	,195	-,141	,255*	1

*significant at 0.05 level **significant at 0.01 level

Regression Analysis

Environmental product innovative performance

As can be seen in table 17 below, the F value for the first model in this regression is not considered significant and the model only explains 2.7% (adjusted R^2) of the variance, therefore this model is not used to interpret the results of the regression analysis. The second model has an F score that is significant at the 0.01 level and explains 30,4% of the variance. The F score of model 3 is significant at the 0.01 level. The model explains 32,7% of the variance, which is a statistical increase compared to model 2. The third model includes the most variables and best describes the conceptual model as presented in the theory section and therefore is used to interpret the results.

Model 3 indicates that company age is positively related to EIP product (,588**). This means that one unit increase in the Log company age results in an increase of EI performance of 0,588. Model 3, as did model 2, also indicates a positive relation between network size and EI performance (,828***). This indicates that a larger network results in larger EI performance. One unit increase in the Log network size results in a 0,828 increase in EI performance. However, the squared term that indicates a non-linear relation is not significant, which means hypothesis 1a is rejected. The B values from the regression analysis for cognitive diversity are not significant and thus hypothesis 2a is rejected.

The product term "Absorptive capacity X network size" has a negative score (-1,892**) that is significant. This relation is visualized by figure 6 below using only the significant values from the regression analysis: the constant, the network size, and the product term of absorptive capacity*network size. The figure shows that the original relation between network size and EI performance was a positive linear one, which after increasing the absorptive capacity starts to become less and less positive. After a certain point a higher level of absorptive capacity even leads the graph to tilt over to a negative relation. The hypothesis on the moderating effect of absorptive capacity assumed a positive effect on an inverted u-shaped relation. The squared variable for a non-linear relation is positive but not significant. Therefore, hypothesis 3a is rejected.

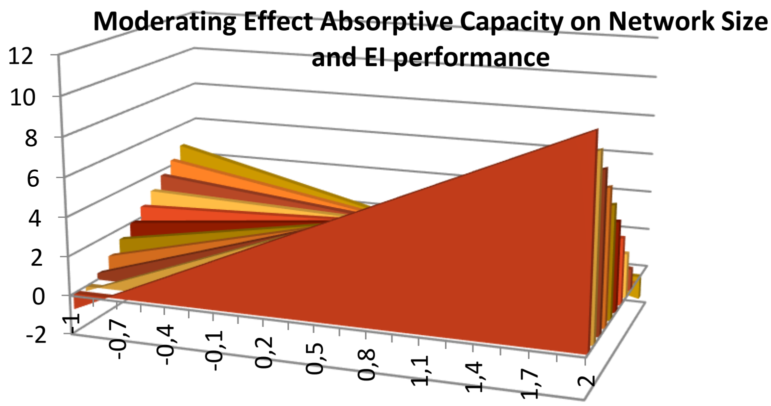


Figure 6) visualization of the moderating effect of absorptive capacity on relation between network size and EI performance (based only on significant values of regression analysis)

The product term of "absorptive capacity X cognitive diversity" is significant and positive (,427**). This relation is visualized by figure 7. The figure is based on the significant values: the constant, and the product term absorptive capacity*cognitive diversity. The other values were not significant in the regression analysis, adding the value for cognitive diversity did not indicate any major changes to the graph. The figure shows that the relation that is assumed is a negative linear one, which is not significant but the moderating effect is still significant. Increasing the absorptive capacity shows the positive effect that was found. The graph becomes less and less negative, and after a certain point it even becomes a positive relation. The squared term, however, is not significant and thus hypothesis 4a cannot be confirmed.

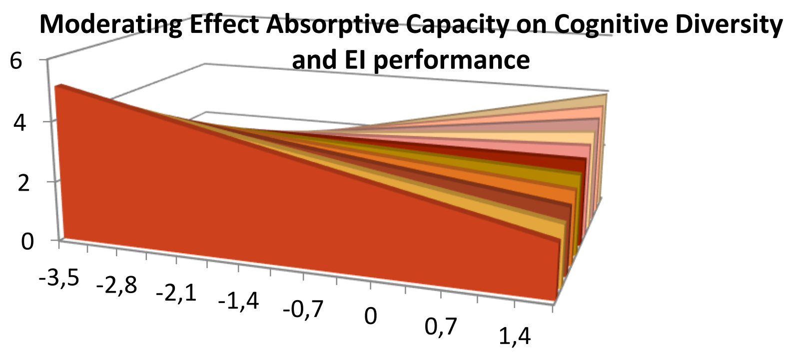


Figure 7) Visualization of the moderating effect of absorptive capacity on relation between cognitive diversity and EI performance (based only on significant values of regression analysis)

Interaction frequency and formality are both not significant and hypotheses 5a and 6a are thus rejected. Informality is significantly related to EI performance. However, the B score is negative (-,238**) which is not as expected. This means that higher levels of informality result in lower EI performance. One unit increase in informality decrease the level of EI performance with 0,238. Consequently, hypothesis 7a is rejected.

Table 17) EIP product regression analysis (values of B and Std. error in brackets are indicated)

	Model 1	Model 2	Model 3
Control Variables			
Age	,228 (,265)	,372 (,229)	,588** (,263)
Size (employees)	,240* (,140)	-,072 (,137)	-,012 (,140)
Independent Variables			
Network Size		,818*** (,249)	,828*** (,267)
Network Size squared		-,001 (,238)	,040 (,277)
Cognitive Diversity		,005 (,064)	-,080 (,079)
Cognitive Diversity squared		-,014 (,023)	,010 (,027)
Interaction Frequency		,098 (,135)	,239 (,150)
Formality		,071 (,096)	,024 (,100)
Informality		-,151 (,092)	-,238** (,108)
Moderator			
Absorptive Capacity	,142 (,213)	-,057 (,198)	-,399 (,325)
Absorptive Capacity X Network Size			-1,892** (,935)
Absorptive Capacity X Network Size squared			,922 (,852)
Absorptive Capacity X Cognitive Diversity			,427** (,187)
Absorptive Capacity X Cognitive Diversity squared			,067 (,061)
R^2	,079	,429	,495
Adjusted R^2	,027	,304	,327
F	1,509	3,451***	2,946***

***significant at the 0.01 level/ **significant at the 0.05 level/ *significant at the 0.1 level

Environmental process innovative performance I

As can be seen in table 18 below the F score for Model 1 is not significant. Therefore, this model cannot confirm or reject any of the hypotheses. Model 2 is significant at the 0.01 level and explains 29,8% (adjusted R^2) of the variance. Model 3 is significant at the 0.05 level and explains 24,6% of the variance, which is less than model 2. The addition of the product terms in model 3 results in lower explanation of the variance and lower significance of the model. Thus, the second model is used to test the hypotheses. Based on model 2 the hypotheses for the product terms cannot be confirmed or rejected. However, model 3 shows that these product terms are not significant. Therefore, hypotheses 3b and 4b are rejected.

Model 2 shows that the control variable of company age has a significant B value (,692**) which indicates that older companies have higher EI performance in the case of process I innovation. Network size is positively and significant (1,182***) related to EIP process I. This positive value indicates that increasing the Log network size with one unit increases the level of EI performance with 1,182. However, the squared term is not significant, thus hypothesis 1b is still rejected. Cognitive diversity is negative and significant (-,219***). This indicates that one unit increase in cognitive diversity, thus one additional type of partner, results in a 0,219 decrease of EI performance. The squared term is not significant and therefore hypothesis 2b is rejected. Interaction frequency is positive and significant (,322*) which indicates that higher levels of interaction result in higher performance. Increasing the frequency with 1 unit (for instance from monthly to weekly, or weekly to daily) the EI performance for efficiency innovation increases by ,322. Hypothesis 5b argued a positive relation and can therefore be confirmed for this model. Formality is not significant and hypothesis 6b is rejected. Informality is significant but negative (-,243**) which is not as expected and thus hypothesis 7b is rejected. This negative value indicates that for an increase of one unit of formality, the level EI performance decreases with 0,243.

Table 18) EIP process I regression analysis (values of B and Std. error in brackets are indicated)

	Model 1	**Model 2**	**Model 3**
Control Variables			
Age	,590* (,329)	,692** (,286)	,710** (,347)
Size (employees)	,108 (,174)	-,124 (,172)	-,142 (,184)
Independent Variables			
Network Size		1,182*** (,312)	1,317*** (,353)
Network Size squared		-,360 (,298)	-491 (,365)
Cognitive Diversity		-,219*** (,080)	-,262** (,104)
Cognitive Diversity squared		-,004 (,029)	,008 (,036)
Interaction Frequency		,322* (,169)	,298 (,198)
Formality		-,067 (,120)	-,028 (,132)
Informality		-,243** (,115)	-,187 (,143)
Moderator			
Absorptive Capacity	,056 (,265)	-,183 (,248)	,016 (,428)
Absorptive Capacity * Network Size			,453 (1,233)

Absorptive Capacity * Network Size squared			-,182 (1,124)
Absorptive Capacity * Cognitive Diversity			,013 (,246)
Absorptive Capacity * Cognitive Diversity squared			-,073 (,081)
R^2	,094	,444	,466
Adjusted R^2	,034	,298	,246
F	1,562	3,033***	2,118**

***significant at 0.01 level/ ** significant at 0.05 level/ * significant at 0.1 level

Environmental process innovative performance II

Model 1 of this regression analysis is significant at the 0.05 level and explains a variance of 10,4% (adjusted R^2) as can be seen in table 19. Model 2 is significant at the 0.1 level and explains 15,1% of the variance. Model 3 is not significant and explains less variance than model 2. Overall, the variance explained and the F values and their significance for these models are very low. Considering this and the low Cronbach's Alpha that was found in the method section for this measure the decision was made not to include this measure and its regression analysis in the answering of the research question.

Table 19) EIP process II regression analysis (values of B and Std. error in brackets are indicated)

	Model 1	**Model 2**	**Model 3**
Control Variables			
Age	,367 (,302)	,405 (,299)	,385 (,359)
Size (employees)	,346** (,160)	,266 (,180)	,333* (,191)
Independent Variables			
Network Size		-,405 (,326)	-,501 (,365)
Network Size squared		-,036 (,312)	,023 (,378)
Cognitive Diversity		,139 (,084)	,138 (,108)
Cognitive Diversity squared		,038 (,031)	,041 (,037)
Interaction Frequency		,056 (,177)	,147 (,205)
Formality		,110 (,126)	,049 (,137)
Informality		-,072 (,120)	-,164 (,148)
Moderator			
Absorptive Capacity	,077 (,243)	,165 (,260)	-,263 (,444)
Absorptive Capacity * Network Size			-,999 (1,277)
Absorptive Capacity * Network Size squared			,629 (1,164)
Absorptive Capacity * Cognitive Diversity			,226 (,255)
Absorptive Capacity * Cognitive Diversity squared			,115 (,084)
R^2	,156	,318	,352
Adjusted R^2	,104	,151	,107
F	2,966**	1,908*	1,438

***significant at 0.01 level/ ** significant at 0.05 level/ * significant at 0.1 level

Hypotheses

Table 20) Overview hypotheses for EIP product

	Expected	Observed	Concluded
Hypothesis 1a	Inverted U	Positive linear	Rejected
Hypothesis 2a	Diminishing returns	No relation	Rejected
Hypothesis 3a (moderator)	Positive (on inverted u-shape relation)	Negative (on linear relation)	Rejected
Hypothesis 4a (moderator)	Positive (on diminishing returns relation)	Positive (on linear relation)	Rejected
Hypothesis 5a	Positive	No relation	Rejected
Hypothesis 6a	Positive	No relation	Rejected
Hypothesis 7a	Positive	Negative	Rejected

Table 21) Overview hypotheses for EIP Process I

	Expected	Observed	Concluded
Hypothesis 1b	Inverted U	Positive linear	Rejected
Hypothesis 2b	Diminishing returns	Negative linear	Rejected
Hypothesis 3b	Positive (on inverted U-shape relation)	No relation	Rejected
Hypothesis 4b	Positive (on diminishing returns relation)	No relation	Rejected
Hypothesis 5b	Positive	Positive	Confirmed
Hypothesis 6b	Positive	No relation	Rejected
Hypothesis 7b	Positive	Negative	Rejected

The tables 20 and 21 above show the hypotheses for both environmental product and process innovative performance. Each table indicates the expected relation, the relation that was found, and the confirmation or rejection of the hypotheses. As is indicated in the tables, for both dependent variables an unexpected positive linear relation was found for hypothesis 1 (network size). Different results were found for hypothesis 2 (cognitive diversity), 3 and 4 (moderator), and 5 (interaction frequency). Both models did not find any relation for hypothesis 6 (formality), and both did find an unexpected negative relation for hypothesis 7 (informality). These findings are further discussed in the conclusions and discussion section.

Robustness Check

A robustness check was executed to validate the use of the measure for the dependent variable. As alternative measures for the dependent variables the following measures were used: % of products environmentally innovated, % of sales gained by environmental product innovations, % of processes environmentally innovated, % of expenditures saved by environmental process innovations. See Appendix VI for the regression analysis tables of the robustness check. The regression models for product innovation (both quantitative and financial) were not significant, therefore no conclusions could be drawn based on these models. The regression models for process innovation (both quantitative and financial) were significant at respectively the 0,01 and 0,05 level.

The findings in the robustness check showed that the positive relation that was found for in the regression analysis was not found for the alternative measures. The negative relation between diversity and EI performance was now found to be positive. This thus means that higher levels of diversity would lead to higher EI performance. When using the quantitative measure for environmental process innovative performance the positive moderating effect of absorptive capacity on the relation between network size and EI performance is found. Also, this same measure does find (negative) moderating effects on the relation between diversity and EI performance (for the both linear and squared term). Furthermore, the positive relation that was found for interaction frequency is confirmed by the alternative measures. Finally, no relations were found for formality and informality. For an overview see table 22.

Table 22) Overview results robustness check for process innovation

	Observed process I	Observed quantitative	Observed financial
Hypothesis 1b	Positive linear	No relation	No relation
Hypothesis 2b	Negative linear	Positive linear	Positive linear
Hypothesis 3b	No relation	Positive linear	No relation
Hypothesis 4b	No relation	Negative linear & negative squared	No relation
Hypothesis 5b	Positive	Positive	Positive
Hypothesis 6b	No relation	No relation	No relation
Hypothesis 7b	Negative	No relation	No relation

Conclusions and discussion

The aim of this research was to investigate the relation between network and interaction characteristics and environmental innovative performance, while also accounting for the possible moderating effect of absorptive capacity. The research question was:

To what extent do network and interaction characteristics influence the environmental innovative performance of companies? To what extent is the relation between network characteristics and environmental innovative performance influenced by the absorptive capacity of a company?

The characteristics investigated were network size, cognitive diversity, interaction frequency, formality and informality. Additionally, absorptive capacity was taken into account as a moderating variable on the relations between network size and cognitive diversity and EI performance. All relations were researched for both product and process innovation. The dependent variables were environmental product innovative performance, environmental process I (efficiency) innovative performance, and environmental process II performance which entailed the items of energy consumption, raw material use and working conditions. The conclusions provided in this section are only based on the environmental product innovative performance and the environmental process I innovative performance. The third measure (process II) did not provide significant models in the regression analysis and is thus not included here.

Network Characteristics

The network characteristics discussed in this research were network size and cognitive diversity. Network size was found to be positively related to environment innovative performance for product innovation and for process I innovations based on improving efficiency. This means that the larger the network of a company, the higher its EI performance. In this research the relation was hypothesized to be an inverted u-shape, which means that after a certain size network the performance decreases again. This inverted u-shape relation could not be confirmed in this research. One explanation for this finding could be the context of environmental innovation that is distinctly different from regular innovation. As argued by Burt (2009) and Gomes-Casseres (1994) when networks become larger it is more likely that additional partners are not able to bring novel knowledge to the table. Dealing with a more complex and multi-disciplinary type of innovation, such as environmental innovation (Chappin, 2008; De Marchi, 2012), might be the reason why increasing numbers of network partners still result in higher EI performance. Additional partners have a higher potential for providing useful and new knowledge when the innovation at hand is more complex and multi-disciplinary. Furthermore, it is possible that the turning point for when a network becomes too large lies further than for regular innovation. It is important to keep in mind that companies working with environmental innovations often find themselves further away from the traditional knowledge base. They are therefore more dependent on others and thus networks can and would be larger. The articles arguing an inverted u-shape relation used data with an average network size between 2 and 9 (Deeds & Hill, 1996; Gilsing et al., 2009; Rothaermel & Alexandre, 2009). The average network size in this research was about 20 and the largest network size was one of 362 partners. This indicates that there is a possible discrepancy in the definition of a partner as these values are in a totally different order of magnitude. The partners in this research were any actors that were collaborated with to generate environmental innovations, and as such it might be more likely that a linear relation exists. The long-term committed relations from the innovation literature are more complex and therefore more prone to coordination efforts, which cause the relation to become negative after a certain point.

For cognitive diversity it was found that the hypotheses for a curve-linear relation with diminishing returns are rejected. The expected effect that, for the first part of the relation, increasing the amount of different partners would improve performance was also not found. The only significant findings indicated a negative linear relation for process I innovation (efficiency). This means that a larger amount of partners results in lower levels of EI performance when it comes to efficiency improvements. This could be due to the fact that this type of process innovation has different characteristics compared to product innovations. Miles et al. (1978) argue that efficiency innovations are overall more incremental rather than radical. They often focus more on one core technology, whereas product innovations and the other process innovations have a broader focus (Miles et al., 1978). Furthermore, increasing the efficiency of production processes is often more about the internal knowledge of a company about how their processes work and how to integrate new processes (Von Krogh et al., 2001). The external knowledge used thus tends to be less diverse for efficiency innovations, and including more diverse partners could have a negative effect on the innovative performance as the knowledge they provide would be redundant but they would still use up resources. Moreover, certain types of organization might be less helpful when it comes to improving efficiency than they would be in other forms of innovation. For instance, a customer might not have the technological knowledge to help with efficiency issues (Edvardsson et al., 2006; De Marchi, 2012). If they were still involved in the innovation process, they would not provide any useful knowledge and still increase coordination efforts. Therefore, companies that had a higher diversity could experience a decrease in their EI performance. This shows the importance of distinguishing different types of organizations in the network. On the other hand, this does not explain why no significant relation was found between diversity and EIP product. A possible explanation for this finding might be that for environmental product innovations it does not matter how diverse the actors in the network are but that the size of the network matters more, as was indicated by the findings on network size.

Interaction Characteristics

The interaction characteristics discussed in this research were interaction frequency, formality and informality. Interaction frequency was expected to be positively related to EI performance, meaning more interaction increases EI performance, as was argued from innovation literature (Czepiel, 1975; Ebadi & Utterback, 1984; Ahuja, 2000; Cavusgil et al., 2003). This research did find that higher interaction frequency results in higher environmental innovative performance for process I (efficiency) innovations. Interacting more often is thus beneficial in the case of process innovations. For EIP product, no statistical relation was found, which means that the frequency of interaction does not influence environmental product innovative performance. It could be that in this case it is not so much about how often partners interact but how long. The same arguments are then valid, that it is hard to transfer complex knowledge, and high levels of trust are required, and more interaction is thus needed.

Formality was assumed to be positively related to EI performance. In this research the formality of interaction was found not to be statistically of influence on the EI performance of companies. A possible explanation can be that the extent to with rules and standard operating procedures are used is not relevant within the context of Dutch culture in businesses. More so, the content of what is being communicated is important as they are more result-driven (Hofstede, 1980; 1994; Li, 1999).

Informality was found to be negatively related to EI performance for product innovation and process I innovation. This means that, in contradiction to the hypotheses, higher levels of informality result in lower EI performance. As argued in the theory section, informal interaction is considered an important stimulant for creativity and can thus play a significant role in innovation (Rothwell et al., 1974). An important difference here could be that the literature on informality and creativity mostly looks at intra-firm situations rather than inter-firm. Moreover, there are also authors that argue against informality being beneficial for innovation. They argue that informal channels are insufficient in transferring the knowledge and resources that are needed and formal channels are required to transfer complex technological knowledge (Rogers, 1982). Moreover, when the knowledge that is gained through collaborations is of very high value, companies perceive the risks to be too high to use informal interaction (Von Hippel, 1989). Informal interaction can then result in information leakage, which makes it harder for companies to appropriate the benefits from innovation and thus places them at a competitive disadvantage (Mansfield, 1985; Schrader, 1991). Keeping in mind that this research investigates the context of environmental innovation, this could be argued as well.

Absorptive Capacity

The role of absorptive capacity was found to be different from what was hypothesized. The positive expected effect on the relations (u-shaped and curve-linear) between network size and cognitive diversity and EI performance was not shown in the results. However, a negative effect was found on the (linear) relation between network size and EI performance in the case of product innovations. This indicates that a larger absorptive capacity lessens the benefits of having a large network for environmental product innovations. An explanation could be that companies with larger absorptive capacity are less inclined is need of large networks as they have high R&D intensity themselves. More network partners are more likely to bring redundant knowledge in partnerships (Gomes-Casseres, 1994; Burt, 2009) and only result in more coordination efforts (Gilsing et al., 2008; Rothaermel & Alexandre, 2009; Faems et al., 2012). This would then lead to a lower performance rather than a higher performance. As also argued by Meeus et al. (2001) companies with a stronger knowledge base that deal with high levels of complexity are less inclined to learn from others. The measure of R&D intensity does indicate the knowledge base of companies and thus explains the negative relation found but does not completely capture the elements of assimilation, transformation and exploitation (Zahra & George, 2002; Camisón & Forés, 2010; Liu et al., 2013). These aspects of absorptive capacity are also important in environmental innovation considering its complex nature and including them could provide different results considering the hypothesis. Thus, it is important to keep in mind that the absorptive capacity measure in this research is only a proxy.

Furthermore, it was found that absorptive capacity has a positive effect on the extent to which a more diverse network (linearly) increases the EI performance of a company for product innovations. This means that companies are indeed better able to use diversity within their networks to increase EI performance when they have higher R&D intensity. The relation was not found for environmental process innovation, which hints again at the fundamental differences between product and process innovations. In the case of environmental process innovation, the absorptive capacity thus did not influence the relation between diversity and performance. This could be due to the fact that process innovations dealing with efficiency are more concerned with learning by doing, as argued by Utterback (1996). This implies that the absorptive capacity is not of importance here as learning by doing is more concerned with tacit knowledge.

Theoretical implications

The findings in this research have some interesting implications for the underlying theories. First, there seem to be some fundamental differences between the context of environmental innovation and that of regular innovation. Second, differences were also found between product and process innovations. To start with the point of context, the findings show that the influence of network size on environmental innovative performance are different than for normal innovative performance. It is found that in this new context there is no point where a larger network would result in a lower performance, or that this point would lie at a different place. Also, as opposed to regular innovation, formality of interaction was not found to be of influence for environmental innovation. Informality, on the other hand, was found to have a negative effect on environmental innovation, which is an aspect of interaction that authors are still divided about for regular innovation. Looking at the differences found between product and process innovation some interesting findings can be indicated. For instance, the diversity of the network has shown to have a negative effect on the environmental innovative performance for process innovations but no effect for product innovations. Also, interaction frequency was found to be important for environmental process innovation but not for environmental product innovations. Overall, this research thus showed that the context of environmental innovation and the differences between product and process innovations provide some essential points of attention.

Practical implications and recommendations

For companies within the technology industry in The Netherlands these findings provide some insights into which aspects they could best focus on. Companies that are dealing with environmental product innovations should focus on growing a large network, as this can increase their EI performance. However, this network does not necessarily need to be diverse. The frequency of interaction and the formality is not relevant for these companies, but they should at least avoid using informal interaction. Companies that are dealing with environmental process innovations should also focus on having a large network. They should, however, avoid high levels of diversity. Interacting frequently with their partners is beneficial for these companies. Formal interaction is again not important and informal interaction should be avoided.

Limitations research and future research

The design of the research has, considering the time and resource constraints, been a sufficient way to provide many interesting insights. The limitations of generalizability and causality have been dealt with by including control variables and a time lag. Additional longitudinal research can ensure higher levels of reliability and validity. Furthermore, future research with a larger sample can bring additional aspects to light and replicate the findings of this research. As this research was confronted with high levels of non-response it could be helpful to perform additional research with the help of a branch organization. Considering the large amount of independent variables in the research using a larger data set could provide additional insight and confirm more of the hypotheses as some values were almost significant. The quantitative nature of this research provided some interesting relations and indicated important differences from regular innovation. Additional qualitative research can provide more understanding of these relations and go deeper into the how and why of these aspects.

This research focused on the technology industry in The Netherlands as this was a fitting context for the research question. Considering the demarcation of this research the findings can only be generalized to the context of the technology industry in The Netherlands. Broadening to other industries can give new insights and show similarities and differences that in turn can clarify the specific nature of environmental innovation. Broadening the research to other countries can bring insights into institutional and other contextual influences on the environmental innovative performance of companies.

The differences found between the product and the process innovation variables indicate that there is still a knowledge gap here. As most innovation research is focused on product innovation, or does not differentiate between product and process innovation, a lack of understanding between their differences exist. Like this research, future research could go deeper into these types of (environmental) innovation and their different network and interaction characteristics. Furthermore, it might also be interesting to look at incremental versus radical innovation, as this was not taken into account in this research but has been indicated in regular innovation literature to be important. Moreover, the different findings for environmental process efficiency innovations indicate that there might be some differences for incremental innovations.

The choice of measures used for the dependent and independent variables can influence the outcomes of a research. The robustness check already showed some different findings for using a different measure for environmental innovative performance. Furthermore, the measure for environmental process innovative performance was separated into two measures based on the factor and reliability analysis. The measure for process II was eventually not usable in drawing conclusions about the hypotheses. The robustness check showed some alternative ways of measuring the environmental process innovative performance. Also, the sample data could have influenced this outcome and perhaps the measure will perform better in future research as it did in previous other research. For network size the number of partners were measured that companies collaborate with for environmental innovations. Considering the large differences with average network size of previous research there is a possible discrepancy in definition of what a partner is exactly. Most likely, the types of research on which the hypotheses were formed consider partnerships of the long-term and reciprocal type. This research, however, included all collaborations that the companies had with any type of partner as long as it was helpful in the generation of the environmental innovation. The measure for cognitive diversity was originally supposed to be a diversity index. Using this measure was not appropriate in this research due to the bias explained in the method section, however, it does influence the results that follow from the regression analyses. Subsequently, investigating the different types of partners and their individual roles and cognitive characteristics could also provide more understanding about EI and networks, as this research shows that there are differences and much is still unknown. This could be done by investigating the characteristics of each partner type separately. For absorptive capacity an alternative operationalization is provided in Appendix VII that could be used to investigate the relation on a deeper level. Frequency of interaction was measure on two scales, but no significant differences were visible. Also, the measure of informality was now constructed of only one item, which could be extended upon to build a more comprehensive concept. The measurements used in this research had a strong theoretical basis, but as mentioned above there is still room for alternatives, and improvements considering specifics of EI and broadening the measures.

In this research a network perspective on firm level was chosen to investigate the concept of environmental innovation. Using different concepts, theories and perspectives could show new findings or confirms the findings of this research. First, the network and interaction characteristics chosen in this research were only the most common concepts as found in literature and future research could focus on other aspects such as: network centrality, network density, trust, and influence tactics. Furthermore, management perspectives can show insights into the strategies of companies concerning environmental innovation and thus zoom in more to an individual level.

To conclude, in answering the research question, it was found that the network characteristics had a significant but not consistent influence on the EI performance. Network size has a positive influence on EI performance but cognitive diversity was only shown to influence the EI performance for process innovations, in a negative way. The interaction characteristics do not all influence the EI performance of companies. Interaction frequency was shown only to positively influence the EI performance for process innovations, but does not influence the EI performance for product innovations. Formality does not influence the EI performance, but informality has a negative influence on the EI performance. The moderating effect of absorptive capacity was only shown to influence the EI performance of companies dealing with product innovations. It has a negative influence on the (linear) relation between network size and EI performance, but a positive influence on the (linear) relation between cognitive diversity and EI performance.

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Appendix I

Data Collection Process

The original sampling strategy of this research was to contact sustainability organizations like MVO to convince them to participate in this research by distributing the online questionnaire amongst their members. Emails were sent to the organizations and people were phoned to convince them. The response was often that they had no time or a policy in which they would not sent any questionnaires to their members. Besides these organizations also several large branch organizations (VNCI, FME and FHI) were contacted through email and by telephone. After speaking to many enthusiastic members of these organizations management would finally decide not to participate in the research. Additionally, the Port of Rotterdam was contacted but they responded that they did not have the time for this research. So, though most contacts were interested in the subject none wanted to participate in the end, which took up a long time of the data collection process. After that, plan B was started to contact all of the companies within the sectors individually. The branch organizations FME and FHI provide member lists on their websites with contact information of links to individual websites. Through these lists the contacts were collected and the sample decided. Some of these contacts were not active anymore and non-response was quite high. This resulted in sending multiple reminders in order to get companies to participate. In the end, the final sample size used in this research was thus 87, which could be a lot better. If future research is done by branch organizations or through their cooperation in distributing questionnaires this could be improved a lot. Companies would be more likely to fill in the questionnaires as they would feel more pressure from above to do so. Moreover, companies get a large amount of requests from students on a daily basis, which makes them less inclined to help them out. As such it is difficult for students to get quantitative data for research such as this. In the case of interviews companies are often more inclined to participate. Concluding, help from larger organizations could be beneficial in increasing the possibilities for students dealing with quantitative research.

Appendix II

Operationalization Table

	Dimension	Indicator	Measurement
Dependent variable			
	Environmental innovative performance	Environmental impact of product innovations in 2013	*Likert scale (completely agree – completely disagree):* *Environmental innovations of my company have resulted in :* - *Improvements in design* - *Improvements in quality* - *Improvements in security* - *New products*
		Environmental impact of process innovation in 2013	*Likert scale (completely agree – completely disagree):* *Environmental innovations of my company have resulted in :* - *Improvements in efficiency* - *Cost reductions from raw materials* - *Cost reductions from energy use* - *Improvements in working conditions*
	Quantitative environmental innovative performance	Number of generated environmental product innovations in 2013	*% of products in 2013 environmentally innovated.*
		Number of generated environmental process innovations in 2013	*% of processes in 2013 environmentally innovated*
	Financial environmental innovative performance	Financial benefits from environmental product innovations in 2013.	*% profit gained through environmental product innovations in 2013*

		Financial benefits from environmental process innovations in 2013.	*% expenditures saved by environmental process innovations in 2013.*
Independent variables			
Network Size		Number of partners involved in environmental product/process innovation between 2011-2013	*How many partners has your company had between 2011 and 2013 with regard to environmental product/process innovations?*
Cognitive Diversity	Diversity in knowledge	Amount of different partners	*How many interactions did your company have with:* *Universities, public research institutes, commercial labs, governmental institutions, industry associations, suppliers, customers, consultancies and competitors?*
Interaction Frequency	Interaction frequency	Number of interactions with partners for environmental innovation between 2011 and 2013.	*How often did your company interact with partners for EI between 2011 and 2013?* *(daily-yearly/rarely-often).*
			How often did you company interact with partners for EI between 2011 and 2013? *(seldom – often)*
Degree of formality	formality of interaction	Terms of cooperation discussed Terms of cooperation documented Use of standard operating procedures Use of formal communication channels	- *Scale (5-point: not at all- completely)* *To what extent are the conditions of your cooperation discussed?* *To what extent are the conditions of your cooperation documented?* *To what extent are standard operation*

			procedures used to coordinate the cooperation? *To what extent does communication follow formal channels?*
Degree of informality	Informality of interaction	Use of informal channels	*To what extent does communication follow informal channels?*
Moderator			
Absorptive Capacity	R&D intensity	R&D expenditure/total sales	*R&D expenditures in 2011 and 2013.* *Total sales in 2011 and 2013.*
Control variables			
Company size		Number of employees	*How many employees did your company have in 2011 and 2013?*
Company age		Number of years in business	*When was your company founded?* *(2013 - answer)*
Financial performance		Sales in 2011 and 2013	*€/year – How much sales did your company make in 2011 and 2013?*
R&D input		R&D expenditures in 2011 and 2013	*€/year – How much did your company invest in R&D in 2011 and 2013?*

Appendix III

Invitation Letter (Dutch)

Geachte meneer/mevrouw,

duurzame innovatie is een veelbesproken onderwerp en voor velen een strategie om concurrentievoordeel te behalen. Vanuit Universiteit Utrecht ben ik momenteel bezig met een onderzoek naar duurzame innovatie en hoe organisaties samenwerken op dit gebied. Voor uw organisatie kan dit onderzoek zeer interessant zijn en uw mening is hierbij van belang.

Graag wil ik u uitnodigen om deel te nemen aan dit onderzoek door het invullen van deze enquête. De vragenlijst kan het beste ingevuld worden door een lid van uw managementteam of, indien mogelijk, een medewerker van de afdeling R&D. De enquête bestaat uit 15 vragen en stellingen en zal maximaal 10 minuten in beslag nemen. Er wordt vertrouwelijk omgegaan met de gegevens in dit onderzoek en deze zullen niet aan derden worden verstrekt. De enquête kan ingevuld worden tot 30 juni 2014.

U kunt de vragenlijst starten door op de onderstaande link te drukken:
http://www.thesistools.com/web/?id=387622

Bij voorbaat dank voor het invullen van de enquête. Heeft u nog vragen of opmerkingen dan kunt u mailen naar: onderzoek.duurzame.innovatie@gmail.com

Met vriendelijke groet,

Marja van der Werff
Masterstudent Science and Innovation Management
Universiteit Utrecht

Appendix IV

Questionnaire (Dutch)

Duurzame Innovatie

Deze enquête gaat over duurzame innovatie. Het doel is om te onderzoeken hoe bedrijven in technologische sectoren samenwerken voor duurzame innovatie. Uw mening is hierbij zeer belangrijk.

Het invullen van deze enquête duurt ongeveer 5 minuten. Er wordt vertrouwelijk omgegaan met de gegevens in dit onderzoek, en deze zullen niet aan derden worden verstrekt.

Bij voorbaat dank voor uw medewerking. Deze enquête graag opsturen voor 31 juli 2014.

Start

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Duurzame Innovatie

Duurzame innovatie
Innovaties zijn vernieuwingen die in de vorm kunnen komen van nieuwe of verbeterde producten en productieprocessen. Duurzame innovatie is een specifieke vorm van innovatie en bestaat uit nieuwe of aangepaste processen, technieken, praktijken, systemen en producten om schade aan het milieu te verminderen of te voorkomen. Dit onderzoek zal met name gericht zijn op duurzame innovatie en maakt onderscheid tussen duurzame product- en procesinnovaties.

1.

Hieronder volgen eerst enkele algemene vragen

In welk jaar is uw bedrijf opgericht?

Hoeveel werknemers (FTE) had uw bedrijf in 2011?

Hoeveel werknemers (FTE) had uw bedrijf in 2013?

Wat was de omzet (€) van uw bedrijf in 2011?

Wat was de omzet (€) van uw bedrijf in 2013?

Hoeveel (in €) heeft uw bedrijf geïnvesteerd in R&D in 2011?

Hoeveel (in €) heeft uw bedrijf geïnvesteerd in R&D in 2013?

Volgende

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2.

De volgende vragen zullen gaan over duurzame productinnovatie

Duurzame productinnovaties zijn nieuwe of verbeterde producten die schade aan het milieu verminderen of voorkomen.

Was er sprake van duurzame productinnovatie in uw bedrijf in de periode van 2011-2013?

- ja
- nee

3.

Duurzame productinnovatie

	%
Hoeveel procent (%) van het totaal aantal producten van uw bedrijf is in 2013 duurzaam geïnnoveerd?	
Hoeveel procent (%) van de totale omzet van uw bedrijf in 2013 is afkomstig van	

duurzaam geïnnoveerde producten?

4.

Vul in op de schaal in hoeverre u het eens bent met de volgende stellingen. De schaal loopt van sterk oneens, oneens, neutraal, eens, tot sterk eens. De vragen hebben betrekking op het jaar 2013.

Duurzame productinnovaties van mijn bedrijf hebben geresulteerd in:

	sterk oneens				sterk eens	n.v.t.
verbeteringen van het productontwerp	○	○	○	○	○	☐
producten van een hogere kwaliteit	○	○	○	○	○	☐
producten met een betere veiligheid	○	○	○	○	○	☐
in nieuwe producten	○	○	○	○	○	☐

Volgende

www.thesistools.com

5.

De volgende vragen zullen gaan over duurzame procesinnovatie

Duurzame procesinnovaties zijn nieuwe of verbeterde manieren om producten of diensten te produceren, die schade aan het milieu verminderen of voorkomen.

Was er sprake van duurzame procesinnovatie in uw bedrijf in de periode van 2011-2013?

○ ja
○ nee

6.

Duurzame procesinnovatie

	%
Hoeveel procent (%) van het totaal aantal processen van uw bedrijf is in 2013 duurzaam geïnnoveerd?	☐
Hoeveel procent (%) van de totale uitgaven van uw bedrijf in 2013 is bespaard door middel van duurzame procesinnovaties?	☐

7.

Vul in op de schaal in hoeverre u het eens bent met de volgende stellingen. De schaal loopt van sterk oneens, oneens, neutraal, eens, tot sterk eens. De vragen hebben betrekking op het jaar 2013.

Duurzame procesinnovaties van mijn bedrijf hebben geresulteerd in:

	sterk oneens				sterk eens	n.v.t
efficiëntere productieprocessen	○	○	○	○	○	☐
kostenbesparingen op het gebied van grondstoffen	○	○	○	○	○	☐
kostenbesparingen op het gebied van energieverbruik	○	○	○	○	○	☐
verbeteringen van de werkomstandigheden	○	○	○	○	○	☐

Volgende

8.

De volgende vragen zullen gaan over samenwerkingspartners. Samenwerkingspartners zijn organisaties waarmee u heeft samengewerkt om tot duurzame innovaties te komen.

Hoeveel samenwerkingspartners, met betrekking tot duurzame innovatie, heeft u gehad in de volgende categorieën in de periode 2011-2013?

Voorbeeld: Als uw bedrijf in deze periode samengewerkt heeft met drie verschillende universiteiten, dan vult u een 3 in. Heeft u met geen een universiteit samengewerkt, dan vult u een 0 in.

	aantal
Universiteiten	
Publieke onderzoeksinstellingen	
Commerciële laboratoria	
Overheidsinstellingen	
Brancheverenigingen	
Leveranciers	
Klanten/afnemers	
Adviesbureaus/consultants	
Concurrenten	

9.

Hoe vaak heeft u gemiddeld interactie gehad met de belangrijkste samenwerkingspartners om tot duurzame innovaties te komen?

U kunt kiezen uit: dagelijks, wekelijks, maandelijks, driemaandelijks, jaarlijks.

	dagelijks				jaarlijks	n.v.t.
Interactie frequentie	○	○	○	○	○	☐

10.

En als u dit zou moeten aangeven op een schaal van zelden tot vaak?

	zelden				vaak	n.v.t.
Interactie frequentie	○	○	○	○	○	☐

Volgende

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11.

De volgende vragen gaan over de manier waarop de interactie verloopt tussen u en uw samenwerkingspartners voor de periode 2011-2013.

Interacties kunnen op een formele of op een informele manier verlopen. Formele interactie is gekenmerkt door een gebruik van standaarden, regels en procedures. Hierin wordt vastgelegd op welke manier er samengewerkt wordt, en hoe de interactie verloopt met betrekking tot specifieke activiteiten en taken.

	Geheel niet				Geheel wel	n.v.t.
In hoeverre zijn de voorwaarden van uw samenwerking expliciet besproken?	○	○	○	○	○	☐
In hoeverre zijn de voorwaarden van uw samenwerking in detail vastgelegd op papier?	○	○	○	○	○	☐
In hoeverre zijn er standard operating procedures (e.g. regels, beleid, formulieren etc.) vastgesteld om de samenwerking te coördineren?	○	○	○	○	○	☐

Formele communicatie
Formele communicatie loopt via formele kanalen die vastgesteld zijn door mensen in een managementpositie.

12.

Formele communicatie

	Geheel niet				Geheel wel	n.v.t.
In hoeverre verloopt de communicatie tijdens de samenwerking via formele kanalen?	○	○	○	○	○	☐

Informele communicatie
Informele communicatie loopt via informele kanalen, buiten de formele structuur om. Deze kanalen lopen van en naar verschillende mensen, ongeacht hun positie, en zijn vaak ongepland.

13.

Informele communicatie

	Geheel niet				Geheel wel	n.v.t.
In hoeverre verloopt de communicatie tijdens de samenwerking via formele kanalen?	○	○	○	○	○	☐

Volgende

www.thesistools.com

14.

Wat is uw functie binnen uw bedrijf?

Geslacht ○ Man ○ Vrouw

Leeftijd 10

15.

Bedankt voor het invullen van deze enquête. Om de enquête in te leveren drukt u op de knop 'einde enquête'. Bent u geïnteresseerd in de uitkomsten van dit onderzoek dan kunt u hieronder uw e-mailadres achterlaten.

16.

Heeft u nog opmerkingen?

Einde enquête

Appendix V

SPSS Data

Factor analysis Environmental Product Innovative Performance; Scree plot:

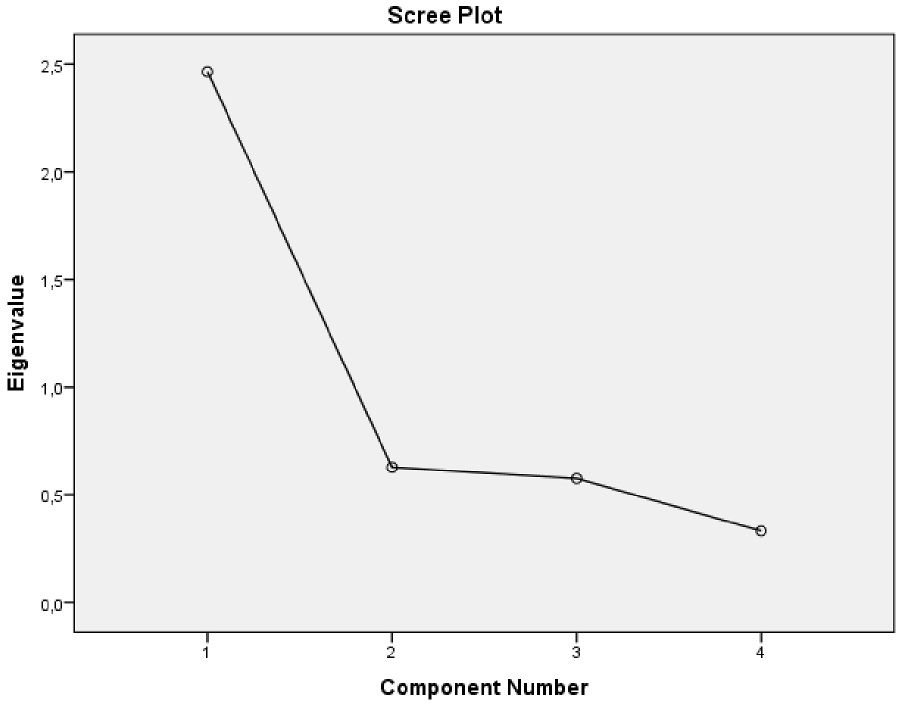

Figure A1) Scree plot Environmental Product Innovative Performance

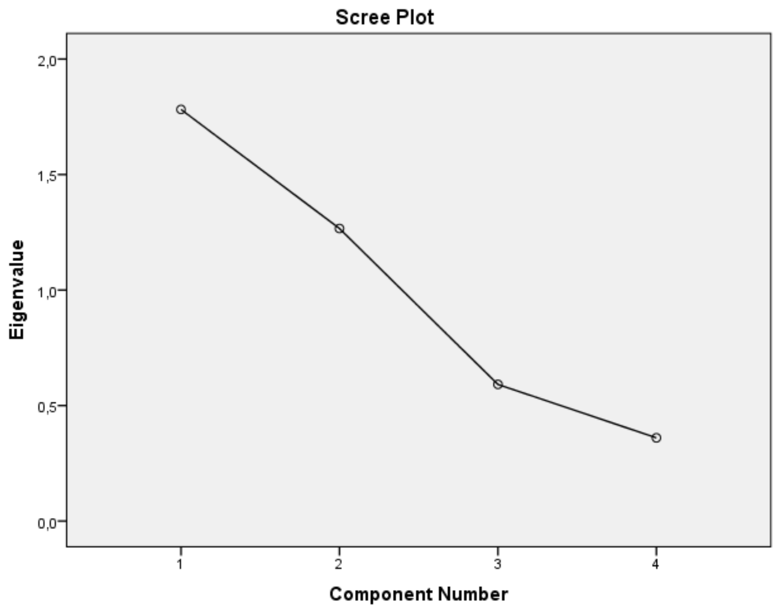

Figure A2) Scree plot Environmental Process Innovative Performance

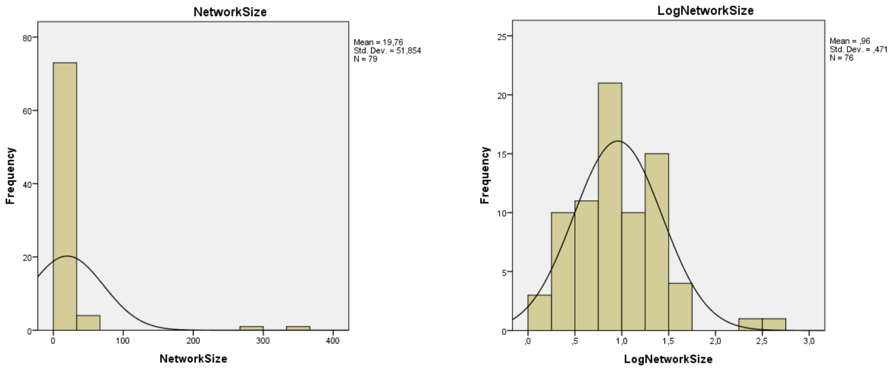

Figure A3) distribution network size before and after logarithmic transformation

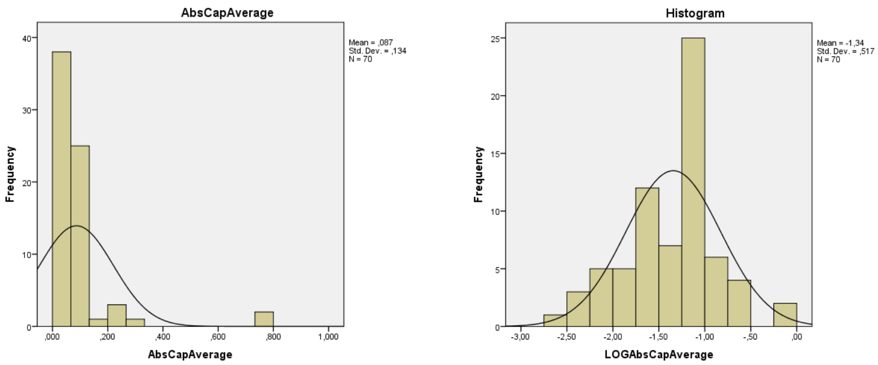

Figure A4) distribution absorptive capacity before and after logarithmic transformation

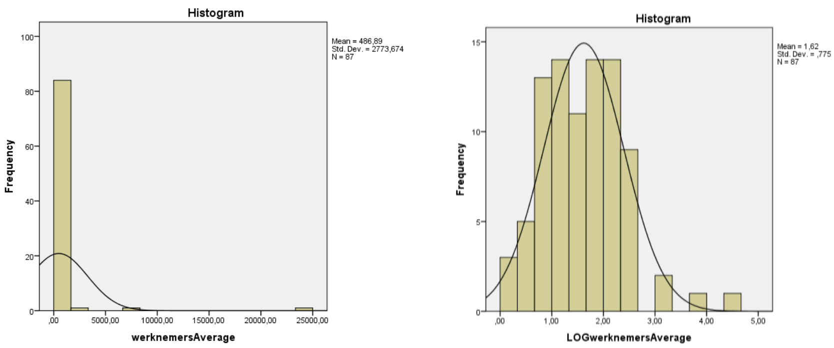

Figure A5) distribution company size before and after logarithmic transformation

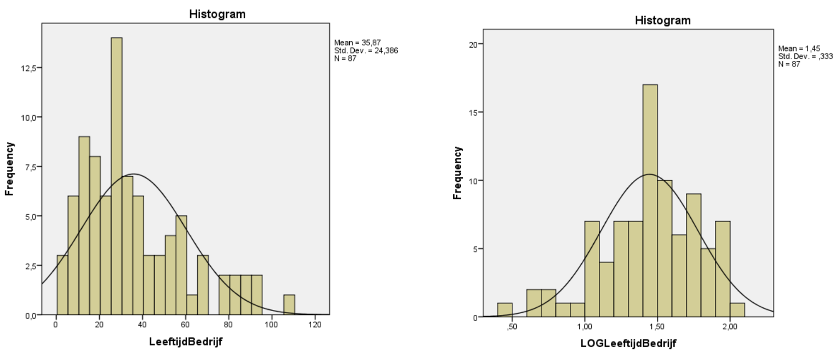

Figure A6) distribution company age before and after logarithmic transformation

Table A1) Skewness check robustness variables

Statistics

		Quanprodinnov	prodvanomzet	Quanproc	procbespaar
N	Valid	73	73	69	69
	Missing	14	14	18	18
Mean		43,30	37,37	24,43	11,58
Skewness		,278	,122	,498	1,295
Std. Error of Skewness		,281	,281	,289	,289
Kurtosis		-1,263	-,914	-,867	1,340
Std. Error of Kurtosis		,555	,555	,570	,570

Statistics

		SQRTQuanprodinnov	SQRTprodvanomzet	SQRTQuanproc	SQRTprocbespaar
N	Valid	73	73	69	69
	Missing	14	14	18	18
Mean		6,1328	5,7412	4,5788	3,0053
Skewness		-,129	-,464	-,083	,406
Std. Error of Skewness		,281	,281	,289	,289
Kurtosis		-1,290	-,795	-,944	-,532
Std. Error of Kurtosis		,555	,555	,570	,570

Appendix VI

Robustness Check

Quantitative Measure

The models for product innovation were not significant, thus no relations could be argued from these models. The quantitative measure for process innovation showed a positive relation for cognitive diversity (,368*), which indicates that an increase of one unit diversity in the network of a company results in an increase in the level of environmental innovative performance of 0,368. Furthermore, the frequency of interaction is found to be positively related (1,229***) to EI performance as well. This shows that a higher frequency of interaction results in higher EI performance. The interaction term of "absorptive capacity X network size" was found to be positive and significant (,686**). Also, the interaction terms of absorptive capacity with cognitive diversity (-,519***) and cognitive diversity squared (-,516***) were both found to be significant and negative. The other variables in this model were found not to be related to the EI performance for process innovations.

Table A2) Regression Analysis Quantitative product [B + Std. Error + Sign]*

	Model 1	**Model 2**	**Model 3**
Control Variables			
Age	-,168 (,894)	-,229 (,878)	-,462 (1,033)
Size (employees)	,451 (,473)	,313 (,527)	,297 (,543)
Independent Variables			
Network Size		,745 (,956)	,677 (1,015)
Network Size squared		-,451 (,915)	-,576 (1,010)
Cognitive Diversity		,103 (,246)	,159 (,290)
Cognitive Diversity squared		-,126 (,090)	-,139 (,100)
Interaction Frequency		,891 (,518)*	,835 (,543)
Formality		-,615 (,369)	-,602 (,377)
Informality		-,022 (,353)	-,004 (,364)
Moderator			
Absorptive Capacity	1,147 (,720)	1,136 (,762)	1,117 (,789)
Absorptive Capacity * Network Size			1,136 (2,435)
Absorptive Capacity * Network Size squared			-1,239 (3,410)
Absorptive Capacity * Cognitive Diversity			-,207 (,540)
Absorptive Capacity * Cognitive Diversity squared			-,307 (,246)
R^2	,051	,234	,238
Adjusted R^2	-,002	,071	,035
F	,969	1,436	1,170

Table A3) Regression analysis quantitative process [B + Std. Error + Sign]*

	Model 1	Model 2	Model 3
Control Variables			
Age	-1,034 (,735)	-,873 (,627)	-,953 (,719)
Size (employees)	-,037 (,389)	-,331 (,376)	-,418 (,378)
Independent Variables			
Network Size		-,052 (,682)	-,358 (,706)
Network Size squared		-,010 (,653)	,146 (,703)
Cognitive Diversity		,230 (,176)	,368 (,202)*
Cognitive Diversity squared		-,047 (,064)	-,090 (,070)
Interaction Frequency		1,327 (,370)***	1,229 (,378)***
Formality		-,234 (,263)	-,227 (,262)
Informality		-,243 (,252)	-,252 (,253)
Moderator			
Absorptive Capacity	-,003 (,591)	,269 (,544)	,375 (,549)
Absorptive Capacity * Network Size			,686 (1,695)**
Absorptive Capacity * Network Size squared			-3,511 (2,126)
Absorptive Capacity * Cognitive Diversity			-,519 (,376)***
Absorptive Capacity * Cognitive Diversity squared			-,516 (,153)***
R^2	,047	,429	,462
Adjusted R^2	-,011	,293	,300
F	,809	3,154***	2,860***

Financial

Again, the models for product innovation were not significant and no relations could be argued there. The financial model for process innovation showed that again cognitive diversity (,402**) and interaction frequency (,684*) are positively related to the EI performance. This indicates that higher levels of diversity and higher frequency of interaction result in higher EI performance. The other variables are again found not to be related to EI performance.

Table A4) Regression analysis financial product [B + Std. Error + Sign]*

	Model 1	**Model 2**	**Model 3**
Control Variables			
Age	6,963 (8,333)	7,724 (8,604)	4,600 (10,096)
Size (employees)	7,501 (4,410)*	6,712 (5,160)	6,838 (5,305)
Independent Variables			
Network Size		4,246 (9,367)	4,506 (9,918)
Network Size squared		2,316 (8,962)	-,187 (9,876)
Cognitive Diversity		-,293 (2,414)	-,042 (2,833)
Cognitive Diversity squared		-1,242 (,880)	-1,248 (,979)
Interaction Frequency		6,697 (5,076)	6,270 (5,307)
Formality		-1,613 (3,611)	-1,445 (3,683)
Informality		,171 (3,462)	,486 (3,553)
Moderator			
Absorptive Capacity	10,015 (6,706)	11,093 (7,469)	10,365 (7,708)
Absorptive Capacity * Network Size			13,984 (23,801)
Absorptive Capacity * Network Size squared			4,138 (33,693)
Absorptive Capacity * Cognitive Diversity			-,912 (5,282)
Absorptive Capacity * Cognitive Diversity squared			-1,627 (2,430)
R^2	,076	,176	,184
Adjusted R^2	,025	,000	-,034
F	1,488	1,003	,845

Table A5) Regression analysis financial proces [B + Std. Error + Sign]*

	Model 1	**Model 2**	**Model 3**
Control Variables			
Age	-,605 (,634)	-,644 (,557)	-,668 (,658)
Size (employees)	-,156 (,335)	-,283 (,334)	-,288 (,346)
Independent Variables			
Network Size		-,786 (,606)	-,805 (,647)
Network Size squared		-,444 (,580)	-,448 (,644)
Cognitive Diversity		,392 (,156)**	,402 (,185)**
Cognitive Diversity squared		,073 (,057)	,070 (,064)
Interaction Frequency		,693 (,329)**	,684 (,346)***
Formality		-,223 (,234)	-,222 (,240)
Informality		-,095 (,224)	-,093 (,232)
Moderator			
Absorptive Capacity	,033 (,510)	,245 (,484)	,248 (,503)
Absorptive Capacity * Network Size			1,283 (2,402)
Absorptive Capacity * Network Size squared			-,420 (2,190)
Absorptive Capacity * Cognitive Diversity			-,245 (,480)
Absorptive Capacity * Cognitive Diversity squared			-,157 (,158)
R^2	,035	,386	,386
Adjusted R^2	-,024	,239	,201
F	,599	2,635**	2,093**

Appendix VII

Absorptive Capacity Operationalization

De volgende vragen zullen gaan over de mate waarin uw organisatie in staat is om kennis te verzamelen, verwerken, transformeren en toe te passen voor innovatie.

8.

Absorptive Capacity

	sterk oneens				sterk eens	n.v.t.
Mijn organisatie is succesvol in het leren van nieuwe dingen.						
Mijn organisatie is in staat nieuwe kennis of inzichten te ontwikkelen die productontwikkeling kunnen beïnvloeden.						
Mijn organisatie is in staat interne kennis (binnen het bedrijf) en externe kennis (vanuit de markt) te identificeren en verkrijgen.						
Mijn organisatie heeft effectieve routines om nieuwe informatie en kennis van partners in de waardeketen te identificeren, waarderen en importeren.						
Mijn organisatie heeft adequate routines om verkregen informatie en kennis te analyseren.						
Mijn organisatie heeft adequate routines om nieuwe informatie en kennis op te nemen.						
Mijn organisatie is in staat eigen bestaande kennis succesvol te integreren met nieuwe informatie en kennis.						
Mijn organisatie is in staat bestaande informatie effectief te transformeren naar nieuwe kennis.						
Mijn organisatie is in staat kansen te grijpen die worden aangereikt door nieuwe externe kennis.						
Mijn organisatie is in staat nieuwe, geïntegreerde informatie en kennis succesvol te bewerken tot concrete toepassingen.						
Mijn organisatie is in staat kennis om te zetten in nieuwe producten.						
Mijn organisatie overweegt constant betere manieren om gebruik te maken van kennis.						