The adoption of digital technology in Industry 4.0

Intellectual property rights and the adoption of digital technology in Industry 4.0 in the context of the innovation ecosystem

BY

M.L. (Marlon) Appels
S4622197

Radboud University

Radboud University, Faculty of Management
MSc Innovation & Entrepreneurship
Nijmegen, June 2022

Supervisor: S.A.M. Menten MSc
Second Examiner: Dr. R.A.W. Kok

Preface

After spending countless hours in the library, consuming liters of coffee, and sometimes even dreaming about this master thesis, I can finally present its final version. By completing this thesis, I proudly round of my master in Innovation & Entrepreneurship, which puts an end to my academic Business Administration career. A moment I could only fantasize about when I started the double degree program in Law and Business 5 years ago.

First and foremost, I would like to take the opportunity to thank my excellent supervisor S.A.M. Menten MSc for the 24/7 support, thorough feedback, and much needed guidance during the process of writing this thesis. I could not have done it without her. Second, I would like to thank all the informants I have had the opportunity to interview for their valuable input. They provided a lot of interesting insights that I could not have done without, and I genuinely enjoyed the interviews and conversations.

Last but not least, I would like to thank my friends and family for motivating and supporting me during the last few months, with special mentions for my friends Tygo Loeffen and Matthias de Leeuw: it took some academic years of pushing each other through, but in the end, we pulled it off!

For now, I hope you enjoy reading my master thesis!

Marlon Appels

Nijmegen, June 2022

Abstract

This research investigates how manufacturing companies manage intellectual property rights (IPR) during the adoption of digital technology, while operating in the innovation ecosystem. With the introduction of Industry 4.0, organizations increasingly go through a digital transformation in which the innovation ecosystem plays a central role. The collaborations between the different actors in the innovation ecosystem were analyzed to gain a better insight into how companies guarantee protection of IPR and safe knowledge exchange. Semi-structured interviews were conducted with eight informants, who were employed at six different organizations that were all concerned with the adoption of digital technology. The analysis shows that companies were sometimes deliberately neglecting both protective measures on foreground IP and protective IPR measures on the ownership of future IPR. Also, the decision to engage in either formal or informal protective IPR measures during the adoption process by means of patents is influenced by the position of a company on the spectrum of the paradox of openness. Lastly, a lenient approach to IPR management by companies positively influences the adoption of digital technologies throughout the entire innovation ecosystem. To conclude, this research shows that a company's position on the spectrum of the paradox of openness in the innovation ecosystem influences IPR management decision making. If a firm has a lower orientation on the general interests of the innovation ecosystem, companies are less inclined to share knowledge and information on digital technology with other actors openly.

Keywords: Adoption, Intellectual Property Rights Management, Innovation, Innovation Ecosystem, Industry 4.0, Digital Technology, Paradox of Openness, Digitalization

Table of contents

1. Introduction

"If you look at history, innovation doesn't just come from giving people incentives; it comes from creating environments where their ideas can connect." – Steven Johnson

Through human history, mankind has always depended on technology to make life somewhat easier. Following up on the 1st, 2nd and 3rd industrial revolution, society finds itself right in the middle of the 4th industrial revolution: Industry 4.0 (I4.0) (Liao et al., 2017). Over the past decade the development of I4.0 has been a popular academic field of research, since it offers new challenges and opportunities to organizations that did not exist before (Bag & Pretorius, 2020; Buer et al., 2018). Past research proves that the needed digital transformation required by I4.0 does not only bring technological challenges, but also contains a wide set of organizational dimensions that need to be considered, intellectual property rights (IPR) management and appropriability strategy being one of them (Bibby & Dehe, 2018; Laursen & Salter, 2014). These organizational challenges force firms to rethink aspects of innovation regarding knowledge protection and IPR, especially when operating in a wider innovation ecosystem (Ilvonen et al., 2018). While operating in the innovation ecosystem, firms seek for opportunities to innovate alongside other actors. If in such a collaboration a new digital technology is adopted, questions about securing IPR quickly rise since multiple actors, each with their individual organizational interest, are involved in the process. This study will therefore focus on the challenges firms face in IPR management and knowledge protection, when adopting digital technologies within innovation ecosystems in the context of I4.0.

Intellectual property rights and knowledge protection

The adoption of digital technology caused by I4.0 creates challenges for firms when it comes to knowledge protection and the management of IPR because boundaries between organizations are blurring (Nayernia et al., 2021). This also entails that established ways of managing IPR during the adoption process of an innovation need to be reviewed and reconsidered. First, a short definition for IPR is in place. IPR are a set of legal rights consisting of patents, know-how, copyrights, industrial design, and trade secrets (Bently & Sherman, 2001). IPR are used to protect an innovation, in which appropriability should enable innovators to profit from their innovations by denying the unauthorized and uncompensated use of the innovation by any other party. When it comes to knowledge protection and IPR, two different types of protection may arise where the main distinction between the two forms is that certain knowledge is patentable,

and other knowledge is not. First, the current (technical) knowledge an organization shares with its network needs to be protected to ensure there is no unauthorized transferring of information (Ilvonen et al., 2018). This includes both tacit and explicit knowledge present in an organization. Second, the appropriability strategy of a firm needs to ensure that the IPR of a potential innovation obtained by that firm, belong to the rightful owner (Laursen & Salter, 2014). Nowadays, it is known that IPR strategy plays an important role for firms' competitiveness (Teece, 2007), which is why it deserves renewed attention in the light of the adoption of I4.0 since sharing of information and innovation lies in the nature of this phenomenon.

Industry 4.0

Where the main focus of this study will be on how firms manage IPR, there are two components that – when combined – distinguish this study from earlier research. First of all, the context of digital transformation in which companies need to manage IPR is what distinguishes this study from earlier research. I4.0 is an ongoing transformational phase for manufacturing organizations, aiming to fully interlink their business functions and production systems with data from the entire lifecycle or end-to-end digital integration (Nayernia et al., 2021). The added value of I4.0 lies in the fact that it creates a digital business ecosystem beyond the boundaries of one single firm or organization, by exploiting the conjunction of independent, data-driven technology among all actors in an ecosystem (Nayernia et al., 2021). Because of the fact that it crosses boundaries between different organizations, the second reason this study differs from earlier research is that it approaches IPR management from an ecosystem-wide perspective. This implies that the relatively new dimensions I4.0 brings along can and should be put into a wider context than just that of an organization or a single company, if only for its interlinked digital character and the distinction between individual organizational interest and ecosystem-wide general interests. Therefore, there has been an increased academical and practical interest in not only the sole phenomenon of I4.0 and its adoption, but on the wider business ecosystem in which organizations find themselves (Benitez et al., 2020; Matt et al., 2021). In this study, the business ecosystem perspective on innovation will be used to investigate implications when adopting I4.0 on an organizational level. (Matt et al., 2021).

Innovation ecosystems

The ecosystem perspective on innovation goes further back in time. Etzkowitz and Leydesdorff (1995) laid the foundation for the introduction of a broader, societal view on innovation, or as

they called it: the triple helix for knowledge based economic development. They expressed the need to involve the relationships between universities, industries, and the government in the research on innovation (Cai & Etzkowitz, 2021). Taking the triple helix as a starting point, the innovation ecosystem literature will provide a useful theoretical lens to investigate the effect it has on IPR management by adopters of digital technology. Just as the introduction of I4.0 does now, ecosystem theory created (and still creates) new possibilities as well as potential bottlenecks, especially for small- and medium sized enterprises (SMEs). Benitez et al. (2020) state that the complexity of I4.0 demands a vast set of capabilities that are hard to find in one organization. Therefore, when interacting in an innovation ecosystem, an actor discloses information about the innovation to attract external actors, but a side effect can be that the value of an innovation may be transferred without any form of compensation: this resembles the paradox of disclosure (Remneland Wikhamn, 2020). Therefore, to prevent unwanted loss of sensitive information on an innovation, knowledge protection in the digital transformation of firms is an essential, but easily overlooked aspect (Ilvonen et al., 2018).

1.2 – Research question & goal

As the digital transformation and implementation of I4.0 is moving forward at a rapid pace, attention for the protection of knowledge and IPR is necessary. This applies to organizations in innovation ecosystems in particular, since more sensitive information is shared among partners. Therefore, this research focuses on how firms should organize and protect (sharing of) knowledge and IPR in the innovation ecosystem, in the context of the digital transformation provoked by I4.0. This research provides an answer to the following question:

How do companies manage IPR in innovation ecosystems when adopting digital technology in the context of Industry 4.0?

The goal of this research is to enhance the understanding of how knowledge and IPR is managed by companies operating in an innovation ecosystem, since uncompensated loss of knowledge and/or infringements of IPR may result in, for instance, loss of value and investments. In doing so, the supportive role that both the government- and the knowledge sector play in the innovation ecosystem will be reviewed. This will especially be focused on the digital transformation towards I4.0, in which the innovation ecosystem can create possibilities for organizations (Benitez et al., 2020).

Scientific relevance

This research is scientifically relevant for 2 main reasons. First of all, there has been little research on how to manage IPR and knowledge protection in the context of I4.0. Although there has been research on IPR strategy by actors in innovation ecosystems, these studies did not take the interlinked character of I4.0 into account (Overholm, 2015; Holgersson et al., 2018). As mentioned, I4.0 is a complex system of interrelated technologies connected through Internet of Things (IoT)-based technologies, acting as shared platforms in the long-term relationships formed by firms in an innovation ecosystem (Benitez et al., 2020). A relevant problem in terms of IPR management and appropriability regimes over the ownership and use of these platforms arises which has not been covered by literature so far. Existing literature on ecosystem theory addresses different roles among actors in innovation ecosystems and the evolution of innovation and IPR strategies that these different roles bring along (Holgersson et al., 2018). However, to date, literature on this matter does not address the possible impact I4.0 and the digital transformation may have on effective IPR management. Furthermore, the combination of the innovation ecosystem-perspective and the way in which all different actors cooperate in adopting digital technology leads to a new perspective through which IPR is managed. Because of the fact that this research investigates IPR management through the perspective of all actors – thereby focusing on the general ecosystem interests instead of individual interests – new insights on how IPR is managed during the adoption of digital technology arise.

Second, Ilvonen et al. (2018) stretch the importance of managing the balance between sharing and protection. This issue is of great importance for how firms set up their IPR strategy when making the digital transformation to I4.0, especially when operating in an innovation ecosystem. Current research shows that protection of knowledge and IPR takes place in both formal and informal ways, but little is known on how to select the appropriate mix. This leaves space for research on how this understanding can be achieved, to also understand when and where a piece of knowledge or information embedded in organizational capabilities generates maximum value or superior performance (Ilvonen et al., 2018). Also, a company's attitude to the paradox of openness may be considered in this trade-off, but for now there is little knowledge on the influence this may have on serving the general interest of the innovation ecosystem (Laursen & Salter, 2014). Again, the interlinked character of I4.0 adds an extra dimension to this question, since all digital technology shares information and data from the entire lifecycle – and therefore: knowledge which might even be patentable – to optimize business functions and production systems (Nayernia et al., 2021).

Managerial relevance

This research is relevant for managers for multiple reasons, but the best way to prove its relevance is by comparing the rise of I4.0 to a similar case, which occurred about 50 years ago. Back then, in the late '60s, big tech companies such as IBM started selling computers with unique software invented by themselves installed on it. Although they were making profit of the hardware that was sold, the software that took a lot of time, money, and energy to invent, was provided freely. This evoked a broad call for legal protection of software. Up to that point, due to the legal boundaries set for patents to be granted, it was impossible to receive any form of legal protection for software since it is intangible. Many lawsuits followed, which in the end resulted in the conclusion that software used in computers was eligible to be patented under certain circumstances (Gottschalk v. Benson, 1972). This showed the pressing need for additional regulations concerning the introduction of hard- and software technologies, since the value firms invested in innovating software was lost due to the lack of protection.

A similar situation currently arises with the introduction of digital technology in firms. As long as there is no effective standard of how to manage IPR throughout the organization, unwanted loss of valuable knowledge regarding digital technology is more likely to occur, especially when operating in the innovation ecosystem. Therefore, managers would benefit from an extra tool to protect the value of firms' innovations in the adoption of digital technology. Although over the years it became evident that digital technology can certainly be patented, to date, both literature and practice have not yet focused on the next step: effectively managing IPR for digital technologies, while considering that the innovation ecosystem can offer support, but be a threat simultaneously.

The structure of this research will be as follows. First, the relevant theory that already exists in this area of research will be provided. Second, the choices made regarding the methodology will be justified. Afterwards, the results will clearly be displayed, to be able to discuss the results and finally draw a substantiated conclusion.

2. Theoretical framework

The next chapter will elaborate on existing relevant theories on the subject of this research. By doing so, the definitions of and relationships between the major concepts mentioned in the introduction will be clarified, eventually resulting in a better understanding of the topic of this research. Also, this theoretical framework will act as the foundation for the legitimacy and feasibility of the actual empirical research that will be conducted. It will also support the formulation of the research question.

First of all, a closer look will be given to how firms adopt digital technology in the context of I4.0. Second, the innovation ecosystem and the different actors involved will be reviewed. Lastly, an elaboration on possible IPR management strategies will be given.

2.1 – Adoption of digital technology

To lay the foundation for this theoretical framework, the adoption and implementation of digital technologies needs to be mapped out and defined. Over time, several different theories have been used to explain the adoption of technology on individual and organizational level. For adoption on individual level, known theories include, among others, the technology acceptance model (TAM) (Davis, 1986), theory of planned behaviour (Ajzen, 1985) and unified theory of acceptance and use of technology (Venkatesh et al., 2003). For adoption on organizational level, available theories comprise of the technology-organization environment framework (Tornatzky et al., 1990) institutional theory (Meyer & Rowan, 1977) and lastly diffusion of innovation theory (DOI) by Rogers (2003). For this research, DOI will be the theory in which adoption of digital technology will be grounded, since the focus will be on organizations adopting digital technology. Also, because of the fact that DOI distinguishes three stages of adoption, it makes it easier to determine in what stage of adoption an organization finds itself in.

As Rogers (2003) described in DOI, the adoption of a technological innovation is influenced by a few distinguishable innovation characteristics: relative advantage, compatibility, complexity, trialability, and observability. Furthermore, he argues that technological innovation adoption is a process that occurs in a few distinguishable steps. The first step is the *pre-adoption stage*, that involves the assessment of all conditions needed for the adoption of an innovation. The second step is the *adoption stage*, which involves the actual decision to adopt the proposed innovation. The last step is the *post-adoption stage*. This stage involves the actual implementation of the innovation. According to Priyadarshinee et al. (2017), ensuring open access to critical technologies such as CPS and cloud computing are a basic

necessity when it specifically comes to the implementation of digital technologies. For this research, the three phases of adoption will act as a starting point to assess the overall adoption status of digital technology throughout the innovation ecosystem. Although these factors are indeed to be considered, the following paragraph of this theoretical framework will provide a more extensive overview of implementation factors for the final implementation stage of digital technology.

Implementation of digital technologies

The successful implementation of digital technology into an organization is a hot topic that has gained the interest of many authors. Therefore, this theoretical framework will use the literature review by Hoyer et al. (2020) as a guideline in order to construct a relevant framework for digital technology implementation as clearly as possible. Since implementation in itself is a broad term, a further definition would be in order to start with. As stated before, the end gate of a successful implementation would lead to a higher level of self-configuration, automation, informatization and decentralized decision-making (Stock & Seliger, 2016). In addition to this more practical impact, organizations should consider an implementation strategy that does not just focus on the technology itself in terms of what it may add to individual projects but set out a strategy that is carried out throughout the whole organization. This organization-wide perspective on implementation strategies is also called a system thinking perspective (Hoyer et al., 2020).

For the critical implementation factors for digital technology, a distinction can be made between external factors, internal factors, and company characteristics. For this research, there are two relevant external factors and one relevant internal factor, as stated by Hoyer et al. (2020). These apply for the different phases of adoption mentioned earlier as well as for the applicability of IPR management throughout the innovation ecosystem.

- *Political support (external):* the role of governmental institutions is broad, simply because several political factors influence the fourth industrial revolution. Political institutions can promote the development of I4.0 by, i.e., reducing taxes for I4.0 related R&D, setting legal boundaries to create an environment in which protection of IPR can thrive, and creating a social system in which education on the specific matter is stimulated (Hoyer et al., 2020).
- *IT standardization and security (external):* end-to-end integration requires the use of the key enablers of I4.0, including cloud computing. In this process, Müller et al. (2018) identified data security issues as one of the main bottlenecks for final implementation.

Next to this, the lack of standardization of new technologies and government policies forces companies to take unpredictable risks when it comes to the acquisition of I4.0 assets (Hoyer et al., 2020).

- *IT infrastructure maturity (internal):* this factor is related to whether the IT infrastructure that facilitates the integration of new technologies is flexible enough to support digital transformation. It refers to the companies' ability to manage the transition to I4.0 and the complexity its technologies bring along. Only if the IT infrastructure of an organization meets a certain degree of maturity, successful transition is possible (Hoyer et al., 2020).

Industry 4.0 technologies

To gain a better understanding of the context in which I4.0 needs to be adopted and implemented by a firm, a closer look at the consequences the technological advancements bring along is needed. As mentioned, digital technology aims to fully interlink business functions and production systems with data from end-to-end digital integration (Nayernia, 2021). So far, however, it has not been discussed by what means a company can achieve end-to-end digital integration of the manufacturing process. Therefore, it will first be discussed what technological implications I4.0 potentially has on the manufacturing process before critical success factors for adoption and finally implementation is examined.

In the pursuit of a digital, industrial ecosystem which is interconnected by integrated solutions, a few technological innovations are to be distinguished. I4.0 is mainly represented by the introduction of five technologies: cyber-physical systems (CPS), Internet of Things (IoT), smart products, cloud computing and business process management (BPM) (Barreto et al., 2017; Xu et al., 2018). While all technologies offer unique features which may provide a suitable solution, CPS is at the core of I4.0 (Kim, 2017). CPS are physical and engineered systems whose operations can be monitored, coordinated, controlled, and integrated by a computing and communication system. The added value of CPS is that it offers a higher level of integration and coordination between physical and computational elements (Xu et al., 2018), which in turn should lead to a more efficient and self-regulatory manufacturing process, or a so-called smart factory. Figure 1 represents a visual overview of how a general CPS is computed.

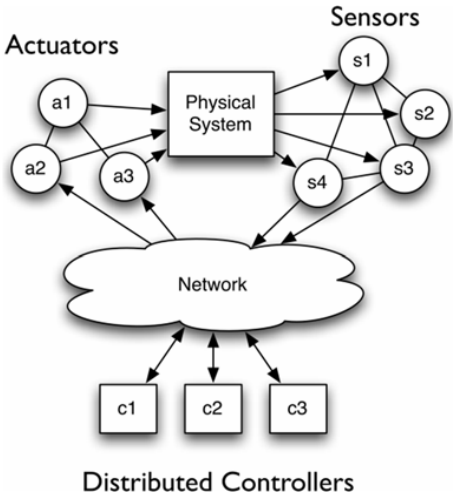

***Figure 1**: Cyber Physical System (Barreto et al., 2017).*

2.2 – The innovation ecosystem

The innovation ecosystem can be defined as "*the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors*" (Granstrand & Holgersson, 2020, p. 3). The main difference between the business ecosystem and the innovation ecosystem lies in the nature of the phenomenon: whereas the business ecosystem mainly involves value capture, the innovation ecosystem focuses solely on value creation, which has a technological nature (Gawer, 2014). As mentioned earlier, the triple helix model is used to express regional relationships between the business sector, the knowledge sector (universities) and the government sector, since this triangle potentially has major influence on the growth of local businesses and therefore on the economy (Benitez et al., 2020; Cai & Etzkowitz, 2021). All sectors are responsible for their own specific task: the business sector is responsible for production, governments should guarantee stable interaction between actors and must set the legal conditions that allow companies to execute IPR strategies, and universities are the source of knowledge and technological advancements (Pique et al., 2018).

These institutions are jointly responsible for creating optimal conditions for the ecosystem in which innovation can thrive. In the innovation ecosystem, a lot of information is exchanged between each actor, be it consciously or unconsciously (Granstrand & Holgersson, 2020). This, combined with increasingly blurring boundaries between organizations as a result of the digital transformation, makes that every actor in the triple helix-model should take an interest in the protection of information. At this moment, however, little is known on how the actors in the ecosystem deal with effective protection of information, be it formal or informal. In the joint context of the innovation ecosystem and the adoption of digital technology, in which

data sharing in collaborations between actors is an essential activity, differing views on the paradox of openness are notable as well. That is why the next paragraph will further elaborate on these two different matters.

2.3 – Intellectual property rights

Intellectual property rights (IPR) give the owning organization the right to protect its invention. It is a set of legal rights consisting of patents, know-how, copyrights, industrial design, and trade secrets (Bently & Sherman, 2001). Knowledge breaks down into tacit and explicit knowledge. Tacit knowledge entails "*knowledge that is embedded in the minds on individual persons. Maybe difficult to express in words, based on experiences*" (Ilvonen et al., 2018, p. 3). Loss of explicit knowledge is related to the digital transformation, since boundaries of organizations are blurring by for instance using cloud computing in the organization (Phelps & Jennex, 2015). Explicit knowledge captured in digital innovations can effectively be appropriated by means of patents (Miric et al., 2019), but the decision to actually protect the value through patents depends on the effectiveness of the protection (Teece, 1986). For manufacturing processes powered by digital innovation, this decision depends on the size of the firm, where it should be mentioned that there are a lot of small firms in the digital industry for whom applying for formal legal protection is a major step (Boudreau et al., 2022).

Appropriability regime

To ensure returns from innovations, the appropriability regime of a company is of great importance. Returns can be ensured by means of IPR, contracts and labor legislation (Hurmelinna-Laukkanen et al., 2008). An important aspect in managing the appropriability regime is the trade-off between secrecy of innovations on one hand, and legal protection with a potential risk of infringement on the other hand, which has widely been discussed in earlier literature (Guo-Fitoussi et al., 2019). This implies that a firm has two choices when adopting an innovation, each with different outcomes. The first would be to keep information on the innovation disclosed within the organization and keep it as a trade secret. This is an example of informal protection. The second option would be to apply for legal protection, but there is one big downside and risk that is grounded in the application process (Amara et al., 2008). In order to receive a patent, and thus formal legal protection, a firm should provide specific information on the innovation. If the patent, in turn, is not granted, the information on the innovation is widely available for all parties that want to profit from it. Therefore, it can sometimes be a less

risky option for a firm to keep the information in the organization by means of informal protection.

If a firm is able to optimize the value that can be obtained through potential IPR present in the organization, the business competitiveness increases drastically, especially in the age of digital transformation (Ilvonen et al., 2018; Reitzig & Puranam, 2009). A successful appropriation strategy is crucial to achieve this optimum, resulting in an extended form of legal protection, consisting of both formal and informal IPR (Reitzig & Puranam, 2009; Roy & Sivakumar, 2011). These choices, however, bring along some implications both on organizational level, as well as on the innovation ecosystem. For example, if a firm deploys a loose patent strategy, it may obtain an advantage from a wide use of its technology on the short term, but it may lose its competitiveness as exclusive provider on the long term since other parties can copy their technology (Holgersson et al., 2018).

Paradox of openness

When making choices on the appropriability regime in the innovation ecosystem, the paradox of openness deserves managerial attention in the context of the open character and vanishing boundaries in both the innovation ecosystem and I4.0. The paradox of openness demands two contradictory yet interrelated elements from an organization: on one hand, the creation of an innovation in an ecosystem requires openness, but the commercialization of innovations requires protection, which regularly manifests itself in the form of protection of IPR (Ilvonen et al., 2018; Laursen & Salter, 2014). Concerning choices made on this paradox, it appears that managerial attitudes towards openness and appropriability are connected (Laursen & Salter, 2014). The figure below is an example of how IPR can be managed through the paradox of openness. It shows how IPR can be managed by firms in both formal and informal ways.

Level of knowledge codification	Level of output tangibility	
	Tangible	**Intangible**
Codified	1. Patents as primary mechanism complemented with copyrights, trademarks and confidentiality agreements	2. Copyrights as primary mechanism complemented with trademarks and confidentiality agreements
Tacit	4. Informal protection mechanisms such as secrecy, complexity of design, lead-time advantage on competitors complemented with confidentiality agreements and trademarks	3. Trademarks as primary mechanism complemented with secrecy, lead-time advantage on competitors and confidentiality agreements

***Figure 2**: Knowledge regimes and appropriability of benefits (Blind et al., 2010).*

Analyzing the ways to manage IPR mentioned above, one notable component is found when relating the management of IPR to the innovation ecosystem in which a firm operates. Especially in the way tacit knowledge can be protected, it is noticed that the focus is on gaining an advantage over the competition. However, assuming the general interests of all actors involved in the innovation ecosystem should be served, gaining a competitive advantage by protecting knowledge for individual interests may not be in line with the purpose of the innovation ecosystem (Ritala et al., 2013). Therefore, from the point of view from the adopters in the innovation ecosystem, it could well be possible that IPR management needs to be re-explained through an innovation ecosystem-wide perspective which differs from how it has previously been described. Only if all the actors in the innovation ecosystem do not just focus on gaining a competitive advantage for themselves, but also on supporting the innovation ecosystem to grow and profit from shared knowledge on digital technology, it can be successful for all actors involved in the long-term.

Earlier research by Lichtenthaler (2010) has shown that medium- and larger sized firms, despite the trend towards open innovation in the ecosystem, are still quite reluctant to provide insight into their manufacturing process. Since larger sized companies need more diverse knowledge on different technological aspects when compared to smaller sized companies, they rely more on internal activities for digital innovation (Lichtenthaler, 2010). Smaller sized companies, in turn, depend on the internal activities and knowledge by larger sized companies for innovation since they themselves do not always have sufficient internal resources to innovate. This may result in a situation where the larger companies, as market determinants,

sometimes choose to keep a closed innovation culture intact by not providing smaller companies insight into their digital manufacturing process and their broad knowledge.

As mentioned, although extensive research has been done on the relationship between the paradox of openness and the appropriability strategy by firms in the service sector, little is known on this matter in the context of managing the adoption of digital technology innovations in manufacturing processes. This is why this research will provide a better understanding on the issue of how IPR is managed in an innovation ecosystem, in which the contradiction between general and individual interests plays an important role.

3. Methodology

This chapter will elaborate on methodological choices made, to eventually provide an answer to the main question of this research. The research method, operationalization, case selection, method of data collection and the analysis technique will be handled, followed by a brief explanation on how research ethics were guaranteed.

3.1 – Research method

To explore how companies manage IPR while adopting digital technologies, with the innovation ecosystem as scope, a qualitative research approach was chosen. This research method was chosen because, as stated earlier, there was no existing literature on the specific matter of IPR management of digital technology, in an innovation ecosystem where boundaries between organizations are increasingly vanishing. Qualitative analysis is a tool that can provide in-depth knowledge on general phenomena (Yin, 2015), and is defined as "*a process of examining and interpreting data in order to elicit meaning, gain understanding and develop empirical knowledge*" (Corbin & Strauss, 2008, p. 2). It is an inductive process, where textual data on how organizations deal with obtaining and protecting IPR in I4.0 settings was collected and analyzed.

An additional reason why a qualitative research approach was chosen is because of its exploratory nature: it is more about theory building rather than theory testing. Because of this reason it can be concluded that quantitative research using surveys would have been less suitable, because the relationships between the concepts were not clarified before. The design of this study was a multi-case study consisting of 8 different interviews. This way, it was easier to identify the key issues of the case, and theoretical saturation was expected to occur (Eisenhardt & Graebner, 2007).

A multi-case study was chosen, in which multiple interviews were conducted within different organizations that were involved in either adopting digital technology in their own organization or supporting other organizations in doing so. Only if multiple organizations were part of the research, key issues on managing IPR in a firm could be derived. By conducting interviews to explore relationships between specific concepts, it was more difficult to draw conclusions about the nature of the relationships, however, it did provide a more general overview on how the concepts relate to each other (Mills et al., 2010). To close this section, it should be mentioned that this research had an inductive approach. As the theoretical framework provided a theoretical base on which further research can be build, this foundation did not

support in answering the research question, and therefore no hypotheses will be given (Yin, 2015). Rather, propositions were formulated in the result section.

3.2 – Operationalization

The theoretical framework, as found in chapter 2, acted as a basis for this operationalization. Three main concepts, each existing of multiple dimensions and items, were distinguished. In doing so, choices were made regarding which dimensions to add into the operationalization. The items were directly derived from the theoretical framework as presented in the previous chapter.

Table 1: Operationalization.

Concept	*Dimensions*	*Items*	*Source*
Innovation ecosystem	Political support	There is need for reduced tax rates on I4.0 related innovative activities	Hoyer et al., 2020
		The organization feels the need for legal boundaries supporting creation and capture of value in terms of IPR	Idem.
	Birth phase	Companies feel the need to unite in business associations	Benitez et al., 2020
		Institutional coordination	Idem
	Expansion phase	Neutral orchestration by the business association and knowledge sector	Idem
		Companies feel the need to work together on complex I4.0 projects	Idem

		The company needs RTOs to provide advanced and expensive technologies	Idem
	Leadership phase	Platform organization with different I4.0 business solutions	Idem
		Business association feels the responsibility for normative and policy support	Idem
		The business association needs the knowledge sector for R&D and knowledge sharing support	Idem
		The company needs RTOs to provide advanced and expensive technologies	Idem
IPR management	Formal IPR	Patents, trademarks, and copyrights	Roy & Sivakumar, 2011
	Informal IPR	Customized software, databases, and trade secrets	Idem.
Adoption of I4.0	Pre-adoption phase	Organization gains knowledge on innovation	Rogers, 2003
		Organization is convinced of the added value of the innovation	Idem

Adoption phase	Organization makes the decision to implement the innovation	Rogers, 2003
	Implementation of the innovation	Idem
Post-adoption phase	The organization looks for support for the decision to implement	Rogers, 2003
	Replacement discontinuance	Idem
	Disenchantment discontinuance	Idem
IT standardization & security	Data security	Hoyer et al., 2020; Müller et al., 2018
	End-to-end integration of I4.0 technologies	Hoyer et al., 2020
	No need for external acquisition of I4.0 assets	Idem
IT infrastructure maturity	Flexible IT infrastructure	Idem
	The organization needs an IT infrastructure that can cope with complex technology	Idem

3.3 – Research setting and case selection

This research focused on the manufacturing sector, since this sector was most likely to explore new fields in R&D on I4.0, and therefore needed a fitting IPR strategy to ensure the companies were able to create new value while also being able to protect the value. The companies that were interviewed were all going through a phase of digital transformation in which their manufacturing process was interlinked by applying new technologies relating to I4.0, while

exploring ways to protect their innovative findings. These firms belong to the business sector of the triple helix model, as their main task is producing goods (Pique et al., 2018).

Besides studying cases at specific companies going through digital transformation, interviews were conducted at innovation consultants that support businesses in their innovation and digitalization processes, since this provided different perspectives on the research subject. Also, to be able to provide a fully substantiated answer to the research question and the sub-questions, an interview has been conducted at an actor in the educational sector. This was done to see how they support companies in their innovation ecosystem with the adoption of digital technology. In addition, an interview has been conducted at a governmental agency responsible for national patent policy, since they were expected to have a broad overview on the current adoption of digital technologies at firms and how they protect them. The table below shows every informant's relevant sector, the reference of each informant for the rest of this study, some information on the organization they work for, and lastly their respective function.

***Table 2**: List of informants.*

Sector	Reference	Organization	Function
Business sector	TruckCorp1	Producer of trucks and other material equipment. Currently transitioning to a production line fully supported by digital technology. The company has an American parent company.	Manufacturing Engineering manager
Business sector	TruckCorp2	Producer of trucks and other material equipment. Currently transitioning to a production line fully supported by digital technology. The company has an American parent company.	European Project manager

Business sector	BikeCorp1	Bike manufacturer with a production line that is fully digitalized by means of, among others, an ERP system. Originally a family business, which attaches great importance to the local interest.	Digitalization manager
Business sector	BikeCorp2	Bike manufacturer with a production line that is fully digitalized by means of, among others, an ERP system. Originally a family business, which attaches great importance to the local interest.	R&D manager
Business sector	Supervisor1	Connecting the manufacturing industry in the east region of the Netherlands using smart industry techniques.	Supervisor of collaborative projects between companies
Business sector	Supervisor2	Connecting different companies in an online ecosystem by exchanging information, based on smart industry techniques.	Community manager & Ecosystem data researcher
Knowledge sector	Education1	A smart industry field lab, where students and companies work together in producing lightweight parts for vehicles.	Business development & Project management

Government sector	Government1	Governmental executive agency, responsible for subsidies and regulations regarding patents.	Government information officer for companies

3.4 – Data collection

The data for this qualitative research was collected through one-on-one semi-structured interviews, in order to provide more depth if certain aspects of the interview asked for it (Bleijenbergh, 2015). Through interviews, an understanding was gained on how organizations formed their IPR strategy on I4.0 related technological innovations, with a special interest for the innovation ecosystem in which they partook. The informants for the interviews were selected based on the criteria that they could all influence decision making in the organization when it came IPR management on digital technology. This resulted in informants consisting of managers, coordinators of manufacturing processes and projects, and advisors. Furthermore, since the use of digital technologies in manufacturing processes is not yet present in every company, it was guaranteed that all informants were employed at a firm that was at least considering the use of I4.0 in their organization.

By conducting semi-structured interviews, the informants were able to express their own view on the themes included in the protocol. The interview protocols can be found in appendix A and B. The advantage of this was that a broader image on how organizations viewed each concept was being explored, unlike a survey, where only a few pre-determined answers can be given. This way of interviewing also ensured that the questions asked within all organizations were roughly the same, which made it possible to derive key components which in the end improved the reliability of the research (Bleijenbergh, 2015).

While conducting the semi-structured interviews, there was one aspect in particular that needed additional questioning: the decision-making process for current IPR management practices. Since the interview protocol did not contain any questions on *why* companies chose formal or informal protection, or how the appropriability regime was established, additional questions were asked during a couple of interviews. Those additional questions followed up after question 14 and 15 from the interview protocol, since those questions indicated the form of protective IPR measures (or, as the results will show, sometimes lack of protective measures) chosen by a company. Examples of the additional questions which were asked were also

included in the interview protocol in appendix A, after question 14. In this way, additional information could be gathered to understand why firms made certain choices on IPR measures.

3.5 – Data analysis

Since this research was inductive in nature, the results were reviewed after which overarching concepts were identified. First of all, the interviews were recorded with the explicit permission of the informant. Every interview has been transcribed using an application called Trint. Since Trint was not always accurate, the interviews were checked and corrected for completeness. After transcribing, the interviews were coded using the application Atlas.ti, which was needed to review all the data and eventually identify overarching concepts. Coding the interviews means that fragments of words are labelled with certain indicators, starting from the operationalization schemas (Bleijenbergh, 2015).

While coding the interviews, a set of predetermined codes originating from the operationalization scheme was used. However, during this process, corresponding answers occurring multiple times did not always relate to the set of predetermined codes. Therefore, more specific codes were derived from the data inductively. This method is also known as accounting-scheme guided coding (Miles & Huberman, 1994). Operating in this way guaranteed that the results would be open for concepts originating from the theoretical framework, as well as to unexpected results that could not have been estimated in advance. The inductive nature of this research allowed this, since primary data collected from the interviews could then be linked to theoretical concepts. Nevertheless, it should be noted that the data was coded without a theoretical bias. To ensure this, the Gioia method has been applied.

The Gioia method is a qualitative analysis method that is characterized by first-order codes and second-order codes (Gioia et al., 2013). This method fitted this research, since it had an inductive approach. First-order codes were developed after thoroughly analyzing and understanding all the interviews. During this process, codes differing from the predetermined codes were constructed. It was decided to only work with first-order codes and not with second-order codes, thus partly diverging from the Gioia method. This was decided because the integrated data structure, including the predetermined codes, all directly related to an aggregate dimension (Gioia et al., 2013). Table 3 shows the integrated Gioia data structure for this research, where the blue shaded concepts represent self-constructed codes, and the red shaded concepts represent predetermined codes:

1st Order Concepts	Aggregate dimension

Table 3: Gioia data structure.

The matter of political support experienced by the organization	Innovation ecosystem
High interaction with other actors in the ecosystem	
Exploring the possibilities for cooperating with other actors in the market	
Working together to find new ways of applicating digital technology	
Taking the lead in the ecosystem and supporting other companies with in-house knowledge	
Strategic thinking about the appropriability regime	IPR management
IPR protection by means of patents and NDAs	
Informal IPR protection by means of trade secrets or on the basis of mutual trust	
Deliberate neglection of protective IPR measures	
A need for pre-collaborative agreements	
Attitude towards the paradox of openness	
Investigating how digital technology can effectively be used by the organization	Adoption of I4.0
Implementing digital technology in the manufacturing process	
Actively using digital technology in the day-to-day practice	
Being able to adopt digital technology without depending on other actors	
Integrated IT system throughout the organization able to cope with change	

During the interpretation, coherent relationships between concepts were sought. Also, unexpected relationships that rose from the distinction between the different organizations studied were noted, after which possible explanations for the differing results are discussed at a later moment in this study.

3.6 – Research ethics

This thesis complies to the ethical requirements for academic research set by the Radboud University. First of all, before conducting the interviews, all informants received a consent form that was read and signed. In this consent form it was agreed that participation of the informants was fully confidential. Also, explicit permission to record the interviews was asked before conducting them. Furthermore, it has been ethically addresses by anonymizing the interviews, to guarantee that there is no sensitive information in this thesis that could do harm to any of the informants or for the organizations they work in. For example, cooperation projects that were still to be launched at the time the interviews were conducted, were not included in the thesis. Next to this, some of the transcripts have been slightly adjusted to ensure complete anonymity. The names of organizations and personal names of informants were not mentioned, but instead cited quotes indicate the specific informant by their particular reference as mentioned in table 2. Also, before publication of this research, the final report was sent to all informants to be previewed.

Next to this, the thesis complied to the rules regarding plagiarism, fabrication of data, and manipulation of data. The interviews were all truthfully transcribed, and all the quotes that were used can all be traced back to an informant. Upon request, the interview transcripts and coding schemes can be obtained.

4. Results

The following section will elaborate on the results found in the interviews and the subsequent analysis of the data. For this analysis, striking results were highlighted, which will act as the starting point for the following chapter where the results are discussed in the light of the theoretical framework. In the previous chapter on the methodology, choices made regarding which organizations and informants were interviewed have already been clarified. This result section will project notable findings with regards to how companies manage IPR while adopting digital technology in the innovation ecosystem.

4.1 – The innovation ecosystem

Since this study focused on IPR management by companies, considering the innovation ecosystem they operate in, the mutual interactions between all different actors in the innovation will briefly be reviewed. Only if these relationships are outlined first, it is possible to understand how companies manage IPR during the adoption of digital technology. While cooperating on digital technology adoption in the manufacturing process, companies mutually share sensitive information and knowledge, which is why the relationships between different actors should be included to understand how IPR on digital technology adoption is managed by firms.

B2B relationships

The results showed that companies, in some cases, highly depend on other companies when operating in the innovation ecosystem, especially when it came to gaining very specific knowledge on advanced digital technologies that were not yet attuned to the manufacturing process they strived for: "*What we wished for, did not yet exist. We cooperate with some Dutch and foreign partners, because nobody in the existing market could give us what we wanted. So, together with some of those partners, we started developing.*" (TruckCorp1). This was confirmed by multiple informants from the business sector: "*The answer is, firms work together very often, period. Often, it concerns specialist knowledge that they do not have themselves, and technology is so advanced these days that they cannot manage it all themselves either. So, companies must make strategic choices about which technology they want to master themselves and which they let others provide.*" (Supervisor1). In line with this, BikeCorp confirmed that they had to be inspired by other companies as well, to ensure the digital technology matched their organization.

Thus, companies often cooperated when it came to developing digital technologies that needed to fit their specific manufacturing process. The results showed that they did not only join forces in such cases of specific technology development, but also when it came to communicating with the innovation ecosystem in a digital environment. As the following quote unveils: "*We have an initiative that is way ahead, in which companies collaborate in a digital environment based on smart industry techniques. […] In this environment, industry partners and clients can share data to communicate digitally.*" (Supervisor2). It can therefore be concluded that for purely substantive issues on digital technology development, the business sector mainly relied on mutual interactions between companies, each bringing their own expertise and specialization to the table.

The dependence of companies on the knowledge sector

The results illustrated that from the business sectors' point of view, the knowledge institute did provide certain supplementary knowledge to the innovation ecosystem. The strength and value attached to mutual relationships between both actors, however, differed. The knowledge institute highly depended on the cooperation and opportunities offered by cooperating companies. This is shown by the following quote: "*To ensure that the digital simulation can communicate with the hardware, open-source programs have been written. This has been done in collaboration with a firm situated in the same industrial area we are in.*" (Education1).

On the other hand, the business sector could operate more independent from the knowledge institute, since they had the necessary knowledge on specific digital manufacturing processes that were developed either in-house, or they had access through B2B partnerships. This perspective has been underlined multiple times: "*Companies do not at all depend on knowledge institutes for adoption. Involvement may speed up the process, but without the other sectors the company eventually also comes to adoption.*" (Supervisor1). Both BikeCorp and TruckCorp agreed to this perspective. So, the informants from the business sector generally agreed on the statement that the digital transformation in their respective company was mainly executed by themselves, without too much input of educational institutes or students.

Yet, it is too short-sighted to conclude that the collaboration between the business and knowledge sector only worked in favor of the latter. Multiple informants from the business sector agreed to the following quote: "*Students can be very valuable for companies, because they visit several companies during their school career where they gain knowledge. They then bring this knowledge into another company in a way that is not perceived as threatening.*" (Supervisor1). So, although some firms mainly saw the collaboration with the knowledge sector

as a one-way transaction, it cannot be ruled out that during that process the students unknowingly contributed to the knowledge and inventiveness of the company.

The supportive role of local hubs

Lastly, the role of the governmental sector in the innovation ecosystem should be understood to comprehend the complex environment in which companies manage IPR. The results showed that an actor not directly related to government agencies played the most important supportive role in connecting different actors in the ecosystem. The following quote shows that local 'hubs' and initiatives were the most important actor in supporting the innovation ecosystem in such a way: "*There are loads of initiatives outside of the government sector. For example, a lot of AI hubs work together with local partners to support, advise and even subsidize companies working on the development and adoption of I4.0.*" (Government1).

This was also mentioned by BikeCorp1, who stated the following: "*We are very active in local collaborations in which not only subsidies play an important role, but we join forces on knowledge exchange with companies closely related to us.*" (BikeCorp1). So, this result confirmed what has earlier been stated by Supervisor1 on the limited role the government fulfilled in the innovation ecosystem. Although these local hubs offered support, it was indicative both TruckCorp and BikeCorp revealed that for their company, sharing knowledge with the ecosystem was not the first, second or third priority. The informants substantiated this by stating that the firms may have had a commercial incentive to keep knowledge on the deployability of a certain digital technology for the company itself, and not for competitors in the market. This form of IPR management, where information is kept inside a company as a trade secret, provides a steppingstone for the next paragraph of this result section.

4.2 – IPR management

Up to this point, the projected results mainly clarified the role of each actor in the innovation ecosystem. In this paragraph, the way in which IPR is managed by firms adopting digital technology will be highlighted. The results illustrated that the position where a company is situated on the "open-closed" spectrum of the paradox of openness influenced decision making regarding protective IPR measures taken by companies, ownership of IPR, and the appropriability regime. However, to fully apprehend those aspects, it is highly important to first gain a better understanding of the matter to which companies are interested in, and occupied with, protection of their innovations and knowledge in the organization. The results showed

divergent visions by multiple companies, wherein a company's position on the spectrum of the paradox of openness played an explanatory factor.

Neglection towards protective measures

First of all, the results revealed that some companies deliberately chose to neglect taking protective measures or were just not much engaged in IPR practices. This broke down into two different kinds of neglection, the first being deliberately neglecting setting up prior agreements on information that is shared with other actors in the ecosystem. Government1, who has a broad overview of the general mindset of entrepreneurs dealing with the adoption of digital technology and sharing knowledge during that process, expressed this as follows: "*Nine times out of ten companies do not make prior written agreements on the protection of knowledge they share amongst them. […] Most companies just want to focus on their core business, and not on all the peripheral matters.*" (Government1).

In line with this statement, Supervisor1 believed that a major part of the ecosystem was mainly driven by mutual trust rather than by written agreements. As an example, BikeCorp catches the eye. BikeCorp characterized themselves as having a high orientation on the general interests of the innovation ecosystem. They attached great importance to sharing knowledge they gained by their own experience on adopting digital technology with other actors in the ecosystem. This has led to them feeling a great deal of trust in other actors in the ecosystem, allowing them to enter a collaboration with such actors without feeling the need to make prior agreements on the knowledge that was shared, therefore not engaging in any form of IPR management practices. Or, as the following quote confirms: "*As far as I know, we never draw up an NDA or make any other agreements about information sharing with other parties before getting into a collaboration. Of course, we do sometimes put a general comment in our emails about the confidentiality, but there are no legal consequences associated with such comments. […] Because we know all of the companies we cooperate with very well, the board would not want us to make a big deal out of the protection of knowledge. We rather just work on the basis of mutual trust."* (BikeCorp2).

So, to summarize, the results showed that deliberately neglecting protective measures before entering a partnership is a way in which some companies manage IPR. By not making agreements before entering a collaboration with another actor, the company risks that the intelligence that is being shared falls into the hands of unauthorized individuals or organizations, without any legal consequences for the actor who runs of with the knowledge. Therefore, a company managing IPR by deliberately neglecting protective measures fully has

to trust its counterparty to handle the information that is shared with care. This yields the following proposition:

Proposition 1a. A company's decision to deliberately neglect protective measures on foreground IP is influenced by a sense of mutual trust between companies.

Neglection for ownership of IPR

The second form of neglection towards protective measures was grounded in (the lack of) agreements made on the ownership of IPR that was created in cooperative projects on digital technology. For instance, TruckCorp clarified that in the major project in which the firm was involved, there were no agreements on who potentially owned future IPR. However, this needs to be nuanced, in the sense that the company did not expect new IPR to be created in this project since they used existing digital technology which was, therefore, not patentable. Although they might not expect it during this project, it was remarkable to notice that the same company did have very clear agreements on the ownership of IPR when it came to other projects and thus were not always deliberately neglecting such agreements on the appointment of ownership.

The main reason for this was that in the first project mentioned, TruckCorp and its partners used existing digital technology, where they only explored new ways to deploy it. Therefore, not engaging in IPR management practices made sense, since using existing technologies does not meet the legal requirements for a technology to be patented. For the second project mentioned, where there were prior agreements on the ownership of IPR, TruckCorp considered the fact that the end result of the collaboration could actually be patentable. This specific project, therefore, asked for a different approach in IPR management practices by the company, which led to prior agreements being made on potential ownership of IPR.

In contrast to this, BikeCorp added the following on this matter: "*For us is it very simple. Of course, we can extensively occupy ourselves with protecting every possible outcome of a project. But this takes so much time, money, and energy which we rather invest in our core business, because if we always lead the way it will bring us just as much as a possible patent*." (BikeCorp1). So, this second form of neglection towards agreements on ownership of potential IPR in collaborations arose from a deliberate, strategical vision. Notable in this sense is that BikeCorp is an open organization in terms of the paradox of openness, as shown by the following quote: "*We are frontrunners when it comes to boosting smart industry trajectories in this region. We organize gatherings with multiple companies, in which we openly share our knowledge on our own experiences with adopting digital technology.*" (BikeCorp1). Because

of the fact that BikeCorp willingly let other actors in the ecosystem have a look in their own organization, thus letting the whole ecosystem profit from possible future IPR, they deliberately chose to neglect possible ownership of future IPR in their collaborations. Therefore, the following is proposed:

Proposition 1b. Deliberate neglection towards protective measures on the ownership of future IPR is influenced by (1) the specific content of a project and (2) a strategical vision based on the attitude towards the paradox of openness.

Formal and informal protection

Although agreements on IPR in collaborations were sometimes neglected because of either the specific content of a project or a strategy based on the attitude towards the paradox of openness, the results also showed that sometimes firms effectively wanted to manage IPR, but then struggled with the contradiction between formally protecting their innovation or protecting it informally by keeping it a trade secret. This had both a patent technical reason as well as a strategic motive. The patent technical reason lied in the fact that it is possible to patent hardware, but it is not always possible to legally protect the software on which the hardware runs. The following quote illustrates: "*We experience a lot of questions about the balance on what to keep as a trade secret and what to formally patent. Most of the times it is a game between hardware and software, in which it is possible to formally protect hardware, but the software that enables the process is kept as a trade secret. Entrepreneurs may have legit reasons to prefer a trade secret over patents, however, the question then is if they handle their trade secret properly.*" (Government1).

So, legal boundaries were sometimes in the way of the optimal situation for companies. Because of this uncertainty, there seemed to be a preference towards informal protection at the firms. This was also confirmed by TruckCorp1, who stated that although it was quite possible that their innovation is patentable, at the moment the company's strategy was not to publish the knowledge and keep it as a trade secret. TruckCorp was on the closed side of the spectrum of the paradox of openness, meaning that they tended to protect their innovations by means of effective IPR measures such as keeping trade secrets. In this way, they are able to commercialize their innovative manufacturing process supported by digital technology and take maximum advantage of its value. Next to this closed attitude towards the paradox of openness, they had lower trust in other actors in the innovation ecosystem. However, it must be noted that this only applied to protective measures on foreground IP, and not on agreements made on ownership of possible future IPR. This was mainly apparent from the fact that they always drew

up Non-Disclosure Agreements (NDAs) before entering a collaboration, ensuring no existing knowledge could end up with unauthorized actors without consequences. This is shown in the following quote: "*With every party we cooperate with, we draw up an NDA beforehand. […] Our legal department reviews every NDA, after which I sign it.*" (TruckCorp1). Overall, the company tended to keep most sensitive knowledge as a trade secret, therefore informally protecting it, by simply not disclosing any knowledge to other actors. If the company did not draw up an NDA, they mostly relied on contracts to control exchange of knowledge with other actors in the innovation ecosystem.

Another remarkable result was found, which is related to the reason why some companies would prefer formal or informal protection of their digital technology. As the following quote by emphasizes: "*If we could eventually patent this new digital technology, we would potentially tap into a whole new business model. We could then sell it as a solution to another manufacturing company.*" (TruckCorp1). This result was also confirmed by TruckCorp2, who stated that this would be an option for the company in the future. So, in other words, TruckCorp would eventually consider formal protection of their innovation, with the purpose of reselling the digital technology for other companies to use in their manufacturing process. By formally protecting their innovation, TruckCorp would characterize themselves as closed on the spectrum of the paradox of openness, because they would not allow other companies to make free use of their innovation. For now, however, they preferred informal protective IPR measures as described earlier.

Opposite to this view on either formally or informally protecting digital technology, however, was the approach by BikeCorp. Both informants of BikeCorp stated that they were keener on protecting knowledge on adopting digital technology as little as possible by means of formal or informal IPR management practices. They rather operated on the basis of mutual trust, as stated earlier, therefore deliberately neglecting protective IPR measures and maintaining an open position on the spectrum of the paradox of openness. Hence, the contradiction between an open- or closed position on the spectrum of the paradox of openness influenced the decision to protect digital technology during the adoption – be it formally or informally. Therefore, the following is proposed:

Proposition 1c. A company's position on the spectrum of the paradox of openness influences its preference for engaging in formal or informal protective IPR measures for digital technology.

Appropriability regime

Next to the form of legal protection, the IPR appropriability regime of companies was a frequent point of attention, which proved to be utmost relevant when focused on collaborations in the innovation ecosystem. First of all, all firms involved confirmed that in a collaboration between them and knowledge institutes, potential IPR was always ownership of the company. However, this was different when it came to the appropriability regime of firms in B2B collaborative projects. Two different views can be distinguished. The following quote represents one of both views: "*Most of the times, companies agree that if a new piece of IP is created, this belongs to the company that provided the crucial knowledge to the project, for that specific piece of new information. As simple as that.*" (Supervisor1). This shows that if there was a prior agreement on the ownership of future IPR present in the B2B collaboration, there was not one party that could always claim ownership, but it depended on who provided the crucial bit of knowledge for the new IPR to arise. The results showed that TruckCorp, in such a situation, prioritized their own interests over the general interests of other actors in the ecosystem, which implied a low orientation on the innovation ecosystem. TruckCorp1 underlined that this low orientation led to a stricter appropriability regime, because they almost always included an agreement in a contract stating that IPR belongs to them.

The second view that was distinguished is best illustrated by the following quote: "*A lot of companies are very closed when it comes to technical specifications of their product, since this is what their revenue model is based on. But when it comes to how they produce and how they deploy digital technology in their advantage, they are very open. […] Companies then want to share their philosophy with other actors in their ecosystem, because they benefit from high-performing companies around them.*" (Supervisor1).

This view was also underlined by both informants from BikeCorp, who stated that they *"are a pioneer and we gladly let other companies around us profit from our knowledge, as long as it is not distracting us from our main revenue model.*" (BikeCorp1). In addition, BikeCorp2 stated the following: "*We mainly work together with partners whose revenue model is not similar to ours. Therefore, we do not have to make strict agreements on IPR which allows every firm in our local surrounding to profit from the general level of knowledge*". (BikeCorp2). So, the results proved that if a company was willing to share its knowledge with other actors in the innovation ecosystem, the appropriability regime – and therefore IPR measures on the adoption of digital technology – tended to be less strict, as long as the revenue model of the other actor was not similar. Taking all of the above into consideration, the following is proposed:

Proposition 1d. The strictness of a company's appropriability regime is influenced by (1) the extent to which a company is oriented on the general interests of all actors in the innovation ecosystem and (2) by similarities in the revenue models of companies involved in collaborations.

4.3 – Adoption of Industry 4.0

Regarding the adoption of I4.0 in companies a few closing remarks and findings still need to be noted, especially on if cooperating in the ecosystem and IPR management in those collaborations contributed to the adoption of digital technologies in companies.

As stated, the B2B partnerships to find new ways to deploy digital technologies proved to be valuable to companies. Even companies which were positioned on the closed side of the spectrum of the paradox of openness, such as TruckCorp, trusted on collaborations as mentioned in the following quote: "*For fitting the technology into the organization, we are part of and rely on a consortium within an educational institute. In this consortium, we have an application for financing with a few other companies that should support final implementation.*" (TruckCorp1). Thus, for adoption, the company cooperated with multiple actors in the innovation ecosystem, which required a certain degree of openness. These collaborations with other companies, however, could only support the adoption of digital technology if all companies involved acknowledged the general interest of the innovation ecosystem that was aimed to be served and all of them willingly opened up their organization to outsiders. In addition, the following was stated on events BikeCorp organized together with other companies: "*We can only make those events into a success if multiple organizations are willing to provide insight into their knowledge on digital technology.*" (BikeCorp1).

So, only if multiple companies in the innovation ecosystem were willing to share insights on existing knowledge, the adoption of digital technology was stimulated. This implies that firms had to be open and flexible about sharing knowledge that may represent value to them, which asked for a lenient approach to IPR management. In turn, this meant that the less firms were engaged in IPR management practices, the more the adoption of digital technology throughout the innovation ecosystem was stimulated. Subsequently, the approach on how IPR is managed in this adoption-supporting ecosystem determined the efficiency. That is why the following is proposed:

Proposition 2. A lenient approach to IPR management by companies positively influences the adoption of digital technologies in the innovation ecosystem.

5. Conclusion and discussion

To provide a substantiated answer to the research question of this thesis, this chapter will be structured as follows. First, a general conclusion will be drawn. Second, both theoretical and managerial implications will be specified. Third, the research limitations will be discussed. Finally, suggestions for future research will be provided.

5.1 – Conclusion

In general, the results distinguished three main concepts that collectively described and defined how firms managed IPR in the innovation ecosystem when it comes to the adoption of digital technology. These concepts were defined in the theoretical framework and in the operationalization, and consist of the adoption of I4.0, the extent to which the organization operates in the innovation ecosystem and IPR management. This study aimed to get a better understanding of the interrelations between these different concepts. Therefore, this research was designed to answer the following research question:

How do companies manage IPR in innovation ecosystems when adopting digital technology in the context of Industry 4.0?

To provide a short answer to the research question, companies in the innovation ecosystem tend to manage IPR in relation to digital technology adoption by forgoing formal protection if possible, whereby both a company's orientation on the general interests of the ecosystem and similarities in the revenue models of other actors they cooperate with influence decision making. If a company does not take formal protective IPR measures, other actors can more easily access knowledge on digital technology, allowing them to speed up their adoption process and therefore the general interests of the innovation ecosystem are served.

Furthermore, protective IPR measures are sometimes deliberately neglected by companies, which is influenced by the sense of mutual trust in other actors in the innovation ecosystem and the position of a company on the spectrum (closed vs. open) of the paradox of openness. Companies with an open position on the spectrum – being that they willingly let other actors profit from their experiences with adopting digital technology, without expecting to be compensated for it – tend to rely on mutual trust and will therefore be less likely to make prior agreements on the protection of IPR. The answer to the research question is most likely not

unequivocal in all cases, since some companies were actively engaging in protective IPR measures. This, however, will be discussed at a later moment in the research limitations.

Since this study contributes to both theory and practice, the implications are split into a theoretical segment and a managerial segment. First, the theoretical implications will be provided in which adoption in the innovation ecosystem and IPR management will be treated separately.

Theoretical implications

First, this study contributes by suggesting that the trade-off a company makes on whether they take protective IPR measures on digital technology innovations – either formal or informal – is influenced by a company's orientation on the general interests of the innovation ecosystem. In the same light, this research also contributes to existing theories on appropriability regimes by a company by suggesting that there may also be deliberate neglection towards protective measures on the ownership of future IPR. The neglection was caused by both the specific content of a digital technology, and by the strategical vision of companies in the innovation ecosystem, whereby the position on the spectrum of the paradox of openness played a role. It was found that this again relates to the company's orientation on the innovation ecosystem, which adds an innovation ecosystem-wide perspective on this theory in which the collective interest of all actors in the ecosystem prevails over individual company interests.

The theoretical implications described above contribute to current theory on IPR management in the following way. Existing theory on IPR management imposes a trade-off between secrecy of innovations on one hand, and legal protection with a potential risk of infringement on the other hand (Guo-Fitoussi et al., 2019). Also, according to present theory, the trade-off between formal and informal protection is made on the base of strategic decisions influenced by aspects of both the organization and the innovation ecosystem (Holgersson et al., 2018). Lastly, existing theory assumes that decisions regarding the strictness of an appropriability regime solely depends on the effectiveness of the protection, which in turn depends on the size of the firm and the product characteristics (Boudreau et al., 2022; Teece, 1986). This research adds an extra component to these current theories by suggesting that a company's orientation on the general interests of the innovation ecosystem play a role in the decision making on protective IPR measures for digital technology.

Second, this study suggests that a company's position on the spectrum of the paradox of openness is influenced by the amount of trust in other actors and the matter of involvement in the local innovation ecosystem. Therefore, this research adds an innovation ecosystem-wide

perspective to the paradox of openness, since the collective interests of all actors involved in the ecosystem were included in the study. According to existing views on the paradox of openness, choices made on the matter to which a company is open in sharing information depends on managerial attitudes towards openness and appropriability, and therefore on the individual interests of a firm (Laursen & Salter, 2014). This research contributes to this theory by suggesting that not only managerial attitudes by individuals or by individual organizations are relevant in this context. This, in turn, brings along another theoretical implication.

Third, this research has shown that in an innovation ecosystem that mainly consists of SMEs, companies are keener on opening up on their innovation process and sharing their IPR with other actors in the innovation ecosystem. This is driven by the mutual trust relationship that companies in the innovation ecosystem have, as well as by prioritizing the general interests of all actors in the innovation ecosystem above a company's individual interests. According to existing research, larger sized firms experience difficulties with opening up on their innovation process and have a strict policy when it comes to IPR managing practices (Lichtenthaler, 2010). In addition, current literature describes that large companies have higher driving forces and can therefore more easily access internal resources when it comes to digital technology (Horvath & Szabo, 2019). This implies that larger companies have less urge to collaborate and share their IPR with other companies. It is shown that for SMEs operating in the innovation ecosystem, this is relatively easier because they feel more urge to cooperate, since they may not always have internal access to specific knowledge on digital technology.

Fourth, this research contributes to the adoption literature from an innovation ecosystem point of view. It is concluded that a lenient approach to IPR management by companies speeds up the adoption of digital technologies throughout the innovation ecosystem. The innovation ecosystem-wide perspective on the paradox of openness is at the base of this conclusion. If actors in the ecosystem place the general ecosystem interests over their individual interests, and companies willingly support each other through the different phases, each organization will move through each phase of adoption at a higher pace since they can access new knowledge more easily. Therefore, this study builds on existing DOI theory by Rogers (2003).

Fifth, an important contribution of this research regarding the different roles each actor fulfills in the I4.0 innovation ecosystem, is that this does not correspond to the triple helix model as proposed by Etzkowitz & Leydesdorff (1995). Because of the fact that the adoption of digital technology by companies is situated in a very specific knowledge domain, little ecosystem-wide general knowledge has been built that enables all actors to fulfill the roles as proposed in the theoretical framework and an alternative interpretation of the roles appeared. The supporting

role is not fulfilled by the central government, but rather by local hubs. Also, in this research the business sector indicates that they do not fully rely on educational institutes to innovate in the field of digital technology, however, firms are inspired by them to a certain extent. The fact that they do not fully rely on knowledge institutes is caused by the high degree of specialization of digital technology, in which every company has their own specific manufacturing needs that must be met. The triple helix model as proposed by Etzkowitz & Leydesdorff (1995), combined with the theory by Pique et al. (2018), assumes that the business sector is responsible for production, the central government must guarantee stable interaction between actors and must set the legal conditions that allow companies to execute IPR strategies, and universities are the source of knowledge and technological advancements. When it comes down to the adoption of digital technology, it shows that these roles are not filled in accordingly to the original triple helix model but are filled in alternatively as described above.

Managerial implications

This research has several practical implications for managers in daily practice. By conducting research on how IPR is managed by multiple companies in the innovation ecosystem, a broad view has been obtained on different IPR strategies. Depending on a company's orientation on the innovation ecosystem, this research allows managers to make decisions on the IPR strategy when going through the digital transformation. If, for instance, a company is very involved in the local ecosystem and can trust on mutual relationships with its different actors, this research shows that a lenient approach to IPR management would positively influence the adoption of digital technology both in the company itself as well as in the whole ecosystem. From a different perspective, it provides managers from companies that are more closed on the spectrum of the paradox of openness the insight that formally protecting (potential) IPR may be beneficial from their point of view. If the organization is on the closed side of the spectrum of the paradox of openness, formal protection would suit the company since accidental loss of value is then prevented.

Another notable practical implication this research offers is that it shows managers the relevance of effective IPR management in the field of digital technology. A lot of companies are deliberately not engaging in any IPR management practices. This research points out that for some companies, it might be good to rethink this strategy. If, for instance, a company steps into a collaboration with a new partner that is not yet familiar and with whom a trust relationship has not yet been established, it might be effective to make prior agreements on the save

exchange of knowledge, even though the same company might normally not partake in such IPR management practices.

5.2 – Research limitations

This research, as any study, has some limitations regarding both methodological aspects and theoretical content. A first limitation lies in the fact that the research was mainly focused on SMEs. Because of this, a distorted picture has arisen especially on the matter of the trade-off a company has to make between formal and informal protection. Now, the conclusion on this subject is that companies do not yet see enough possibilities and feel enough support to actually formally protect their digital innovation, thus preferring informal protection. This outcome could have been different if other companies than SMEs were involved in this study, since they may have more legal support and/or financial possibilities to formally protect their innovation.

A second limitation of this research is the fact that the study was conducted within an innovation ecosystem that is quite alike, located in the South-Eastern region of the Netherlands. This means that the relationships in this particular ecosystem were studied in depth. However, the fact that only one ecosystem could be included in the study should be considered a limitation that makes the results more difficult to generalize. This does provide a steppingstone to paragraph 5.3, since this limitation could be solved by including multiple ecosystems in further research.

Third, the number of interviews of this thesis was limited when accounting for the subject at hand. Because this research had a qualitative approach, the eight different interviews that were conducted bring some limitations to the study. Since, due to the design of this research, only a limited number of interviews were conducted, it could well be possible that other aspects that were not covered play a role in the way firms protect digital technology. In further research, interviewing multiple informants per company and per sector would provide a solution for this limitation. This also means that the results of this study cannot be generalized blindly. However, it must be said that this study was not designed to generalize its findings, but its aim was to clarify certain patterns in the innovation ecosystem. Also, to improve reliability of the research, the interviews were transcribed and coded precisely, by which transparency is provided. Adding up to this, it must be considered that although only two specific manufacturing companies were interviewed, multiple interviews were conducted with supervisors and government officers who oversee the market and can therefore provide a well-considered assessment of the general situation at companies.

A fourth and last limitation of this research is that while conducting the interviews, informants could offer self-assessed measures of some phenomenon. This is known as the self-reporting bias, which occurs if there is a deviation between the way in which an informant reports on a certain subject and the true value of the subject (Donaldson & Grant-Vallone, 2002). To avoid the self-reporting bias, the interviews were conducted using neutral- and non-suggestive language. Also, since the interviews were anonymized, informants were less likely to provide socially desirable answers to the questions.

5.3 – Suggestions for further research

Based on the limitations, I also present some suggestions for further research. As the previous paragraph showed that this research was conducted in the South-Eastern region of the Netherlands, and therefore more or less within an innovation ecosystem that was quite alike, it would be interesting to put this study in a different national regional – or even international – context. In the interview with TruckCorp2 it was briefly mentioned that there were not only collaborations on national level, but on the international level as well. If the same study is conducted in different ecosystems, different outcomes regarding, e.g., the mutual trust between actors in the innovation ecosystem can be expected which may in turn influence IPR management decision making. Also, by conducting this study in multiple innovation ecosystems, the generalization of the results can be improved.

In addition, further research could consider the social aspect of the innovation ecosystem in which an organization operates, and the role they play in IPR management decision making. Social aspects were not included in this study, but in some interviews it turned out that factors like social control, local company cultures, and regional behavior patterns seemed to influence IPR management decision making. If future research considers the different social aspects of the innovation ecosystem in which a company finds itself, a broader image could be formed on which social factors are decisive for IPR management by a company.

Another way to generalize the results of this study is by performing quantitative research, instead of the qualitative research that has been conducted. Since this study provides a few propositions that could be tested in a larger sample size, further quantitative research could present findings that are generalizable for a larger group of companies.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, *50*(2), 179-211.

Amara, N., Landry, R., & Traoré, N. (2008). Managing the protection of innovations in knowledge-intensive business services. *Research policy*, *37*(9), 1530-1547.

Bag, S., & Pretorius, J. H. C. Relationships between industry 4.0, sustainable manufacturing and circular economy: proposal of a research framework. *International Journal of Organizational Analysis*.

Barreto, L., Amaral, A., & Pereira, T. (2017, Jun 28-30). Industry 4.0 implications in logistics: an overview. Procedia Manufacturing. 7th Manufacturing-Engineering-Society International Conference (MESIC), Vigo, SPAIN.

Benitez, G. B., Ayala, N. s. F. n., & Frank, A. G. (2020). Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. *International Journal of Production Economics*, *228*.

Bently, L., Sherman, B. (2001). *Intellectual Property Law*, Oxford, Oxford University Press.

Bibby, L., & Dehe, B. (2018). Defining and assessing industry 4.0 maturity levels - case of the defence sector. *Production Planning & Control*, *29*(12), 1030-1043.

Bleijenbergh, I. (2015). *Kwalitatief onderzoek in organisaties*. Den Haag, Netherlands: Boom Lemma uitgevers.

Blind, K., Evangelista, R., & Howells, J. (2010). Knowledge regimes and intellectual property protection in services: a conceptual model and empirical testing. In *The handbook of innovation and services*. Edward Elgar Publishing.

Boudreau, K. J., Jeppesen, L. B., & Miric, M. (2022). Profiting from digital innovation: Patents, copyright and performance. *Research Policy*, *51*(5), 104477.

Buer, S.-V., Strandhagen, J. O., & Chan, F. T. S. (2018). The link between industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda. *International Journal of Production Research*, *56*(8), 2924-2940.

Cai, Y. Z., & Etzkowitz, H. (2021). Theorizing the Triple Helix model: Past, present, and future. *Triple Helix, 7*(2-3), 189-226.

Corbin, J., & Strauss, A. (2008), *Basics of Qualitative Research 3e.* London: Sage.

Davis, F.D. (1986). A technology acceptance model for empirically testing new end-user information systems: theory and results. PhD thesis, *Sloan School of Management, Massachusetts Institute of Technology*.

Donaldson, S. I., & Grant-Vallone, E. J. (2002). Understanding self-report bias in organizational behavior research. *Journal of business and Psychology*, *17*(2), 245-260.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of management journal*, *50*(1), 25-32.

Etzkowitz, H., & Leydesdorff, L. (1995). The Triple Helix -- University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development. *EASST Review, 14*(1), 14-19.

Frank, A. G., Gerstlberger, W., Paslauski, C. A., Lerman, L. V., & Ayala, N. F. (2018). The contribution of innovation policy criteria to the development of local renewable energy systems. *Energy Policy*, *115*, 353-365.

Gawer, A. (2014). Bridging differing perspectives on technological platforms: Toward an integrative framework. *Research Policy, 43*(7), 1239-1249.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational research methods*, *16*(1), 15-31.

Gottschalk v. Benson, 409 U.S. 63 (1972). https://www.casebriefs.com/blog/law/patent-law/patent-law-keyed-to-adelman/patent-eligibility/gottschalk-v-benson/

Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. *Technovation*, 90-91, Article 102098.

Guo-Fitoussi, L., Bounfour, A., & Rekik, S. (2019). Intellectual property rights, complementarity and the firm's economic performance. *International Journal of Intellectual Property Management*, *9*(2), 136-165.

Himang, C., Ocampo, L., Obiso, J. J., Bongo, M., Caballes, S. A., Abellana, D. P., ... & Ancheta, R. (2020). Defining stages of the Industry 4.0 adoption via indicator sets. *Engineering Management in Production and Services, 12*(2), 32-55.

Holgersson, M., Granstrand, O., & Bogers, M. (2018). The evolution of intellectual property strategy in innovation ecosystems: Uncovering complementary and substitute appropriability regimes. *Long Range Planning*, *51*(2), 303-319.

Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?. *Technological forecasting and social change*, *146*, 119-132.

Hurmelinna-Laukkanen, P., Sainio, L. M., & Jauhiainen, T. (2008). Appropriability regime for radical and incremental innovations. *R&d Management*, *38*(3), 278-289.

Ilvonen, I., Thalmann, S., Manhart, M., & Sillaber, C. (2018). Reconciling digital transformation and knowledge protection: a research agenda. *Knowledge Management Research & Practice*, *16*(2), 235-244.

Kim, J. H. (2017). A Review of Cyber-Physical System Research Relevant to the Emerging IT Trends: Industry 4.0, IoT, Big Data, and Cloud Computing. *Journal of Industrial Integration and Management-Innovation and Entrepreneurship, 2*(3), Article 1750011.

Laursen, K., & Salter, A. J. (2014). The paradox of openness: Appropriability, external search and collaboration. *Research Policy*, *43*(5), 867-878.

Liao, Y., Deschamps, F., Loures, E. d. F. R., & Ramos, L. F. P. (2017). Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. *International Journal of Production Research*, *55*(12), 3609-3629.

Lichtenthaler, U. (2010). Intellectual property and open innovation: An empirical analysis. *International Journal of Technology Management*, *52*(3/4), 372-391.

Matt, D. T., Molinaro, M., Orzes, G., & Pedrini, G. (2021). The role of innovation ecosystems in Industry 4.0 adoption. *Journal of Manufacturing Technology Management*, *32*(9), 369-395.

Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American journal of sociology*, *83*(2), 340-363.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. sage.

Mills, A. J., Durepos, G., & Wiebe, E. (2010). *Encyclopedia of case study research* (Vol. Volume 2 /). SAGE.

Miric, M., Boudreau, K. J., & Jeppesen, L. B. (2019). Protecting their digital assets: The use of formal & informal appropriability strategies by App developers. *Research Policy*, *48*(8), 103738.

Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, *132*, 2-17.

Nah, F., & Lau, J. (2001). Critical factors for successful implementation of enterprise systems. *Business Process and Management Journal, 7*(3), 285-296.

Nayernia, H., Bahemia, H., & Papagiannidis, S. (2021). A systematic review of the implementation of industry 4.0 from the organisational perspective. *International Journal of Production Research*, 1-32.

Overholm, H. (2015). Collectively created opportunities in emerging ecosystems: The case of solar service ventures. *Technovation*, 39-40, 14-25.

Phelps, M., & Jennex, M. E. (2015). Ownership of collaborative works in the cloud. *International Journal of Knowledge Management (IJKM)*, *11*(4), 35-51.

Pique, J. M., Berbegal-Mirabent, J., & Etzkowitz, H. (2018). Triple Helix and the evolution of ecosystems of innovation: the case of Silicon Valley. *Triple Helix*, *5*(1), Article 11.

Priyadarshinee, P., Raut, R. D., Jha, M. K., & Kamble, S. S. (2017). A cloud computing adoption in Indian SMEs: Scale development and validation approach. *Journal of High Technology Management Research*, *28*(2), 221-245.

Reitzig, M., & Puranam, P. (2009). Value appropriation as an organizational capability: The case of IP protection through patents. *Strategic Management Journal*, *30*(7), 765-789.

Remneland Wikhamn, B. (2020). Open innovation change agents in large firms: how open innovation is enacted in paradoxical settings. *R&D Management*, *50*(2), 198-211.

Ritala, P., Agouridas, V., Assimakopoulos, D., & Gies, O. (2013). Value creation and capture mechanisms in innovation ecosystems: a comparative case study. *International Journal of Technology Management*, *63*(3-4), 244-267.

Rogers, E.M. (2003). *Diffusion of innovations* (5 ed.). New York: Free press.

Roy, S., & Sivakumar, K. (2011). Managing Intellectual Property in Global Outsourcing for Innovation Generation. *Journal of Product Innovation Management*, *28*(1), 48-62.

Stock, T., & Seliger, G. (2016). Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia Cirp 40*: 536–541.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, *15*(6), 285-305.

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal, 28*(13), 1319-1350.

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *Processes of technological innovation*. Lexington books.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, *56*(8), 2941-2962.

Yin, R. K. (2015). *Qualitative research from start to finish*. Guilford publications.

Appendix A: Interview protocol

Introductie voorafgaand aan het interview: momenteel ben ik bezig met het schrijven van mijn master thesis voor de master Innovation & Entrepreneurship aan de Radboud Universiteit. In mijn onderzoek focus ik op hoe om wordt gegaan met intellectuele eigendomsrechten op innovaties die vallen onder de noemer van Industrie 4.0 en de bescherming van data, met daarbij speciale aandacht voor het innovatie ecosysteem waarin een organisatie zich bevindt. Allereerst zou ik willen vragen of u ermee akkoord gaat dat ik dit interview opneem. Dit interview zal uiteindelijk worden getranscribeerd, geanalyseerd en uiteraard geanonimiseerd.

Introductie:

1. Zou u het bedrijf en de werkzaamheden die worden verricht kort kunnen introduceren?
2. Zou u uw eigen functie binnen het bedrijf kort willen omschrijven?

Industrie 4.0:

3. Op welke manier wordt Industrie 4.0/digitale technologie (of systemen die hieronder vallen) momenteel ingezet binnen de organisatie zelf?
    a. Eventueel doorvragen over data security, flexibiliteit van de IT-infrastructuur en hoe om wordt gegaan met het inpassen van complexe technologie.
4. Hoe is het Industrie 4.0 systeem dat wordt gebruikt in de organisatie tot stand gekomen?
    a. Is dit uit interne R&D voortgekomen, of is het van buitenaf aangetrokken?
5. Hoe wordt het in gebruik nemen van Industrie 4.0 gerelateerde systemen en het doen van R&D gestimuleerd van buitenaf?

Innovatie ecosystemen:

6. Op welke gebieden werkt het bedrijf/de instelling samen met andere partijen om de technologie in te passen binnen de organisatie?
7. In welke fase van het innovatie ecosysteem bevindt de organisatie zich?
    a. Geef uitleg over de verschillende fases.
8. Welke informatie wordt verkregen en gedeeld tijdens het uitvoeren van nieuwe projecten/het maken van de digitale transformatie?
9. Afhankelijk van de fase waarin de organisatie zich bevindt: waar zit het verschil in de soort informatie die wordt gedeeld en de fase waarin de samenwerking/het innovatie ecosysteem zich bevindt?

10. Hoe waarborgt de organisatie de veiligheid van informatie die wordt gedeeld tijdens de samenwerking?
    a. Worden regels betreft eigendom van informatie/kennis overeengekomen voordat de samenwerking begint? Of is dit iets wat zich gedurende de samenwerking ontwikkelt?
    b. Betrek eventueel op de fase waarin het innovatie ecosysteem zich bevindt.
11. In hoeverre is de organisatie afhankelijk van andere instellingen om tot innovatie/nieuwe manieren/digitale transformatie te komen?
12. Hoe kijkt u aan tegen geldende regelgeving met betrekking tot het patenteren van innovaties?
    a. Eventueel: in hoeverre heeft het bedrijf invloed op/contact met degene die het beleid maken?
13. Is er contact/samenwerking met kennisinstituten over aan Industrie 4.0 gerelateerde ontwikkelingen?
    a. Zo ja: hoe wordt dit contact ervaren? Is dit nuttig? Worden er vanuit de kennisinstituten eisen gesteld aan het delen van informatie?

Intellectueel eigendom:

14. Hoe ziet de IE-portefeuille eruit? Is er formele bescherming, of met name informeel?
    a. Indien sprake van bescherming: waar is de beslissing om formeel dan wel informeel te beschermen op gebaseerd?
    b. Indien geen sprake van bescherming: is hier bewust voor gekozen, of is er simpelweg geen rekening mee gehouden?
15. Hoe is de juridische bescherming van mogelijke innovatie binnen de organisatie geregeld?
    a. Op welke manier (formeel/informeel)? Is hier een speciale afdeling voor, wordt dit ondersteund door een externe partij? Is dit een gestandaardiseerd proces?
16. Wordt met partners gesproken over juridische bescherming van innovatie?
    a. Op welk moment? Geïnitieerd door wie?

Appendix B: Interview protocol governmental agencies

Introductie voorafgaand aan het interview: momenteel ben ik bezig met het schrijven van mijn master thesis voor de master Innovation & Entrepreneurship aan de Radboud Universiteit. In mijn onderzoek focus ik op hoe om wordt gegaan met intellectuele eigendomsrechten op innovaties die vallen onder de noemer van Industrie 4.0 en de bescherming van data, met daarbij speciale aandacht voor het innovatie ecosysteem waarin een organisatie zich bevindt. Allereerst zou ik willen vragen of u ermee akkoord gaat dat ik dit interview opneem. Dit interview zal uiteindelijk worden getranscribeerd, geanalyseerd en uiteraard geanonimiseerd.

Introductie:

1. Zou u de organisatie en de werkzaamheden die worden verricht kort kunnen introduceren?
2. Zou u uw eigen functie binnen het bedrijf kort willen omschrijven?

Industrie 4.0:

3. Is er binnen het de organisatie aandacht voor de introductie/adoptie van digitale technologie?
    a. Zo ja: hoe wordt dit onderwerp bij bedrijven/instituten aangekaart en gestimuleerd?
4. Wordt de interesse/aandacht voor het maken van de digitale transformatie andersom gestimuleerd door bedrijven, aan het octrooicentrum? Is hier veel vraag naar?

Innovatie ecosysteem:

5. Ervaart de organisatie vanuit bedrijven veel vragen/problemen wat betreft het invoeren van digitale technologie (specifiek in het productieproces)?
6. In welke fase van adoptie ervaren jullie dat de meeste bedrijven zich bevinden?
    a. Zijn deze bedrijven vooral werkzaam in de productie/industrie sector of bevinden zij zich in andere sectoren?
7. Welke ondersteuning geven jullie op dit moment aan bedrijven die de digitale transformatie willen maken?
8. Hoe uit de ondersteuning van bedrijven zich vooral? Is dit tijdens de aanvraagprocedure, controleren of het eventueel te octrooieren is, subsidies of iets dergelijks? Of door het samenbrengen van geschikte/geïnteresseerde partijen uit het ecosysteem?

9. Wordt dit op maat per bedrijf gedaan?
10. Komt deze ondersteuning voort uit overleg met bedrijven door te luisteren naar waar zij tegenaan lopen? Of hebben jullie ook eigen initiatieven of aanwijzingen voor regelgeving?
11. Hoe biedt de organisatie ondersteuning aan kennisinstellingen op het gebied van digitale technologie?

Intellectueel eigendom:

12. Zijn er tot op heden (voor zover u weet) patenten verleend voor uitvindingen op het gebied van digitale technologie aan productiebedrijven in Nederland, of lopen er aanvragen voor? Zo ja, hoeveel zijn dit er ongeveer en verwacht de organisatie een toename?
    a. Worden productieprocessen die ondersteund worden door digitale technologie over het algemeen aangemerkt als 'software met een verder technisch effect'? Hierdoor zou het namelijk te octrooieren zijn.
13. Merkt de organisatie op dat er bij bedrijven verschuivingen ontstaan wat betreft de manier waarop eventuele digitale technologie innovaties worden beschermd? Wordt dit sneller/minder snel openbaar gemaakt (en daarmee de aanvraagprocedure gestart), of hebben bedrijven de neiging om dit meer binnenshuis te houden?
    a. Wat zijn over het algemeen de beweegredenen van bedrijven om wel/geen octrooiaanvraag te starten? Heeft dat bijv. vooral te maken met kosten, vorm van bescherming of door wat concurrenten doen?
14. Op welke manier ondersteunt de organisatie informele bescherming van kennis, door bijvoorbeeld te adviseren over de bescherming van zelf ontwikkelde software?