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Haakon Thue Lie

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Thesis for the Degree of
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Trondheim, May 2020

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Abstract

Trade secrets are secrets with commercial value that are delimited and managed. They may concern technology, business strategy, customer data and any information of value to a business that is intentionally concealed. Recently the EU, Norway and the USA amended the legal framework for trade secrets. The changes concern how trade secrets can be objects for licencing and knowledge-sharing, as parts of collaborations and open innovation.

Trade secrets need management from their creation to their end. The management needs are different from those for other intellectual property that can be published. When trade secrets are part of the knowledge flow in collaborations and open innovation, there is a need for managers to balance openness and secrecy. This thesis, with five papers, research that balance and how trade secrets are managed.

The first three papers discuss openness and access to research results from collaborative projects between universities and industry. The studies build on the analysis of the contractual agreements in 483 research projects. The results comprise a framework that can help unravel the complicated contractual provisions and their interrelationships, as well as new perspectives on lead time advantages.

The fourth paper investigates how SMEs use trade secrets to create competitive advantages from knowledge exchange and open innovation. This paper builds on survey data from 3871 Norwegian SMEs with a novel set of questions that include differentiation between establishing and using trade secrets. The paper also proposes how to set a baseline for future studies on the effect of the new legislation.

The fifth paper concerns teaching and learning trade secret management. The threshold concepts framework is an educational lens well suited for teaching subjects that are transformative and troublesome, as trade secret management is.

Trade secrets are part of the broader concept of appropriation mechanism. For researchers, it is crucial to understand better the shift from trade secrets for keeping knowledge secluded, to trade secrets used for knowledge transfer in open innovation. There is then no dichotomy of openness and secrecy. There is a process of knowledge appropriation where trade secrets blend with other mechanisms for the management of innovation.

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Then many thanks to my main supervisor, professor Roger Sørheim for the long and lasting support through all the phases of an industrial PhD. I appreciate that very much, as well as being sent out on teaching assignments. Roger and the colleagues at the Stratforr research group have been instrumental in expanding my views. I have appreciated the research seminars, social activities and the coffee machine. Special thanks to professor Endre Sjøvold for teaching and discussions on teams. That research will go on!

I have had the privilege of belonging to a second research environment with friends and colleagues in Gothenburg, at the Center for Intellectual Property – CIP. My co-supervisor, Professor Ulf Petrusson at the Gothenburg School of Business, Economics and Law at the University of Gothenburg has been a crucial part of the project. He has provided much of the foundation for this research and been a great challenger and discussion partner. Dr Bowman Heiden has contributed with contacts to researchers and professionals, with professional insight and with organising CIP-forum, as have Anna Holmberg Borkmann and the other colleagues at CIP. Many thanks also to the CIP chair, professor emerita Margareta Wallin Peterson for the efforts in aligning NTNU with CIP.

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In CIP, NORSI and at NTNU I have enjoyed researching, teaching and socialising with Dr Knut Jørgen Egelie. He changed the course of this project extensively by proposing a study of a thousand contracts. And so, we did – almost 4000 of them – creating three papers in this thesis and a book chapter. It has been great fun, lots of learning, great discussions, whiteboards filled with drawings - and a willingness from Knut Jørgen to see the ever-expanding project through. Thanks!

The papers in this thesis have had the benefit of comments, suggestions and reasoned rejections from many readers and reviewers. Special thanks to Dr Harald Irgens-Jensen for suggestions and comments on a Norwegian language book chapter I wrote with co-author Knut Jørgen. Thanks to Morten Landsgård for discussions on e-learning and trade secrets. My work has benefited from help and suggestions from the Norwegian Industrial Property Office, Innovation Norway, the Research Council of Norway, NTNU TTO and researcher at the Institute for Energy Technology, IFE.

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When staying in Trondheim, I have been so fortunate to have family all around. The last four years I have been almost monthly staying with my cousin Marianne Lie and her husband, Leif Martin (as above). The long discussions on education and trade secrets with Leif Martin resulted in a paper – however, the contribution to the thesis from Marianne and her sister Kristin Lie Lysholm, husband Jørgen Lysholm and their families offering hospitality and a harbour in Trondheim, has been crucial.

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“Problems worthy of attack, prove their worth by hitting back."
– Piet Hein, Grooks

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"… control over secrecy and openness invoke four different, though in practice inseparable, elements of human autonomy: identity, plans, action, and property. They concern protection of what we are, what we intend, what we do, and what we own."
Sissela Bok, Secrets: On the Ethics of Concealment and Revelation (1989)

1 Introduction

1.1 Background, scope and definitions

1.1.1 Trade secret management

Trade secrets are secrets with commercial value that are delimited and managed. They may concern technology, business strategy, customer data and any information of value to a business that is intentionally concealed. Businesses that collaborate may share trade secrets. Such use of trade secrets implies management of the secret knowledge exchange. From that comes the research question of this thesis: "*How are trade secrets managed in collaborations and open innovation?*"

There are legal definitions in both the EU and the USA comprising business value from secrecy, a clear definition of what the secret is, and measures to protect the secret from disclosure. From the media, there is an impression that trade secrets are destined to last forever. They rarely do, as the information becomes public by many different mechanisms. Patent applications are frequently trade secrets for 18 months until the patent system requires a publication. Computer code may be proprietary and secret until the owners decide that open source code aligns better with their business model. The profit of a firm may be a trade secret until annual reporting makes it public. Trade secrets can be stolen in a cybercrime attack, or they can be misappropriated by an employee leaving for a competing firm. More important, firms use trade secrets as objects for licencing and sharing knowledge as part of collaborations and open innovation, as is the topic of this thesis.

Business managers rank the importance of trade secrets for protection of innovation higher than trademarks, patents, copyright and designs (Eurostat 2016). Trade secrets are used for all types of innovation: product including services, process, marketing and organisational innovations. Trade secrets often are compared to patents as an alternative for appropriating product or process innovations (S.J. Graham 2004; EUIPO

2017). Most of the literature discuss trade secrets given these two innovations types, but the use of trade secrets is apparent also in marketing innovations (European Commission 2013c; Mark F. Schultz and Lippoldt 2014; Lippoldt and Schultz 2014) and organisational innovations (Liebeskind 1997; Costas and Grey 2016).

Trade secrets need management from their conception. This need contrasts with copyright, that requires little or no management. As an example: In software development, copyright management in the form of knowing who wrote what parts is performed automatically by the systems most firms use for version control of the code. However, if parts of the code are to be trade secrets, there is a need for management of those parts of the code.

Trade secret management is a subset of intellectual property (IP) management and innovation management, and of importance to innovation studies. The management objective is to create and keep competitive advantages using trade secrets, typically for innovation appropriation, knowledge sharing and licensing. A firms ability to govern and share its knowledge, and search for and license-in others knowledge, is vital to open innovation. Thus, research on trade secret management is of importance to innovation studies. There is sparse literature, and there is an ontological issue that may obscure the relevance to innovation studies: Trade secret management may also be viewed as a part of "openness management", the way organisations reveal their knowledge. Openness and secrecy are yin-yang-like, in that trying to manage one of them, implies managing the other as well. Resnik (2006), from a philosophy of science point of view, concludes that the ethical key pillar of openness in science must be weighed and balanced with justified needs for secrecy.[1] Contractor (2019), with a business management perspective, presents openness and secrecy as a balancing act for the firm, with a possible optimum level of disclosure. In university-industry collaborations, these perspectives meet. If they are understood as a dichotomy of

[1] He continues the argument with how science-internal conflicts are best solved by regarding the aims of each research project. Conflicts with other parts of society will need trade-offs both for epistemic values such as truth and for non-epistemic, such as welfare or human rights.

openness and secrecy, then the agreements between the parties in collaborative research will reflect that. However, if secrecy and openness is understood more as a process, a balancing act, then research collaborations and open innovation may improve from that.

Three of the papers in this thesis examine the current situation and suggest changes to the management of openness and secrecy. One of the papers concerns how small and medium-sized enterprises (SMEs) establish and use trade secrets, and the last paper concerns the teaching of trade secret management. The papers are focused on specific topics and levels, as presented later in this introduction. Together with this cover essay, they answer the research question "*How are trade secrets managed in collaborations and open innovation?*". This answer cannot be complete. The scientific exploration of trade secret management is in its infancy. There is a lack of theory and empirical studies. The contributions from this thesis are mainly to the understanding of trade secrets in collaboration and open innovation - how individuals, firms and organisations, and the innovation system relates to the management of trade secrets.

	Title and authors
Paper 1	Access and openness in biotechnology research collaborations between universities and industry *Egelie KJ, Lie HT, Grimpe C, Sørheim R*
Paper 2	A New Advantage: Trade Secrets, Academic Secrets and Lead Time Advantages in Collaborative Research between Universities and Industry *Lie HT, Egelie KJ*
Paper 3	Monopoly spotting – an empirical study of research collaborations between universities and industry *Lie HT, Egelie KJ, Grimpe C, Sørheim R*
Paper 4	Trade Secret Management in SMEs *Lie HT, Tobro M, Hansen TB*
Paper 5	Teaching Trade Secret Management with Threshold Concepts *Lie HT, Hokstad LM, O'Connell D*

Table 1 List of papers

All papers in this thesis, see Table 1, address gaps in the literature, as discussed in the next section 1.1.2. The literature I build on, see chapter 3, is from several fields. Secrecy and trade secrets are studied in innovation studies, jurisprudence, economics, management, sociology and psychology. I position this thesis as interdisciplinary with innovation studies as a primary contributing field. The gaps I present are related to that tradition of studies. However, there are gaps in other fields as well, that I address. As examples, both Paper 5 and Paper 2 discuss gaps in jurisprudence. Paper 2 points to legal issues and contract management. Paper 5 addresses epistemological questions that close gaps in legal studies, such as how openness is not addressed in the curriculum for legal studies from M. Evans (2012). As another example, the distinction from Paper 4 between the establishment and use of trade secrets closes gaps in economics where Klasa et al. (2018) empirically study how trade secrets affect capital structure decisions. This study could have benefited from the distinction from Paper 4. Workforce mobility affects trade secrets in use differently than those that are only established. In conclusion, the gaps I address next are, however, from the innovation studies literature.

1.1.2 Relevance. gaps and main contributions to research

Trade secret management, as distinct from the study of trade secrets as a legal concept, is described in the literature. Nonaka and Teece (2001) discuss trade secrets in the context of managing industrial knowledge, including examples of managerial practice in American firms. Hemphill (2004) describes the strategic management of trade secrets as influenced by the legal, the organisational and the market environments. The lines of work from David Teece and that of David Hannah (Teece 2018b, 1986) and (David Hannah 2005; David Hannah et al. 2019) both concern management of trade secrets. Teece includes trade secrets in intellectual property management and from that in strategic decision-making. Hannah's view builds on how rules on trade secrets impact the management and the procedures in a firm. There are recent contributions on specific topics, such as Holgersson and Wallin (2017) that studies the joint management of patents, trade secrets and publications. Also, there are studies of trade secrets and how to understand the new legislation in the EU and the USA. However, the prior literature does not discuss trade secrets in the context of collaborations and open innovation. This thesis contributes to closing that gap by consistently researching trade secrets in view of knowledge exchange – where secrecy, is a part of open innovation and collaboration. From that, this thesis elucidates the apparent paradox of secrecy being a part of openness.

B. Hall et al. (2014) review the literature on how firms choose between informal intellectual property, such as trade secrets, and formal, such as patents and copyright. An important conclusion is that managers mix the many appropriation mechanisms. Their review points to gaps that this thesis addresses. They conclude that "… *secrecy is not the most effective and frequently used informal appropriation method. The narrow focus of the theoretical literature creates a gap between the theoretical models and the empirical work in this area."* The first part of that conclusion refers to mechanisms such as lead time advantages that this thesis discusses. The second part points to the lack of theory that is of use to empirical research but also to a further gap: the type of data. A large part of the research data in this thesis is a type of data new to innovation studies, as we use archived collaborative research agreements.

In 2020 Norway will follow the EU and implement new legislation on trade secrets (Norwegian Government 2019). In 2016 both the EU parliament and the US congress passed harmonising legislation on trade secrets (European Commission 2016; Congress of the United States of America 2016).[2] The motivation for amending the laws is that the policy- and lawmakers find that better legislation will improve knowledge exchange and trade. Paper 4 discusses some of the backgrounds for the law amendments and the extent of support from empirical research. As more firms

[2] The laws on trade secrets in for example China and Japan are adapting too, but build on unfair competition law, as the Paris convention do. See James Pooley's blog on https://www.ipwatchdog.com/2019/04/25/progress-international-effort-harmonize-trade-secret-protection/id=108579/

intentionally use trade secrets for the appropriation of innovation, the need for management of trade secrecy arises, and that is an obvious relevance of this thesis.

A more subtle relevance is that discussed in Papers 1 and 3: Trade secrets and publications are both parts of the management of openness. When new research platforms and innovation ecosystems are developed, trade secrets enable “knowledge monopolies” and “closed circles” as discussed in Paper 1. In Paper 3, we show how the two-by-two model from Paper 1 can be used to spot emerging monopolies and closed circles, and thus allows policymakers and managers to enforce or encourage openness and dispersed access.

This model, the two-by-two matrix presented in Paper 1, is a significant research contribution for management of trade secrets. The understanding from the model is a prerequisite for managing trade secrets in collaborative research. The model can also be the basis for future innovation management tools, as discussed in Paper 3. Further, the models for contractual negotiations and re-negotiations in Paper 2 is a similar research contribution that can be extended to management tools.

In Paper 4, there is an ontological clarification of establishing and using trade secrets that matters both for an innovation manager and further research. Also, there is a recommendation that empirical studies on the effect of the new EU and US legislation for SMEs should build on changes in licensing rather than the perceived importance of trade secrets for business. This baseline is important for understanding SMEs’ engagement in open innovation, where we also contribute with data on enabling procedures and cluster participation.

In Paper 5, a contribution to teaching is a proposed curriculum for trade secret management that use threshold concepts as a framing. Also, there are ontological and epistemological contributions from the discussion on simultaneities and counterintuitivity.

Table 2 further identifies to what extent each paper contributes to close research gaps in the literature. The gaps that the papers close are all related to the research question on how trade secrets are managed in open innovation and collaborations: In Papers 1 and 3 we create a much-needed distinction between openness and access. Trade secrets are not open, but as the thesis discuss, there may be grades of secrecy, and no openness-secrecy dichotomy. Further, trade secrets may as patents be shared exclusively or non-exclusively and may be part of a revealing strategy. Paper 2 closes a gap in that the literature uses lead time advantages ambiguously. The paper presents an explanation and a definition. Paper 4 closes gaps in how the literature model trade secrets and ask questions in surveys. Paper 5 closes a gap in that the literature has not proposed any framework for teaching trade secret management.

No.	Brief title	Gaps and references	Contributions to closing gaps
1	Access and openness in biotechnology	Contract studies have not been used in studies of univeristy-industry relations (Perkmann et al. 2013)	Contracts are the basis for our survey. We demonstrate a new method for research and management.
		Access and openness have not always been separated in prior studies.	We demonstrate empirically that a distinction is useful.
2	A new advantage	Lead time advantages have not been defined in a consistent way (OECD 2005; OECD/Eurostat 2018; B. Hall et al. 2014)	We disclosed how lead time advantages is a mix of three concepts and comprise trade secrets, and presented a definition in line with classic innovation studies, such as (Von Hippel 1982)
		Though the theory of incomplete contracts indicate that research collaborations should renegotiate, the literature suggests no framework for renegotiations within the project, only when it ends	We suggest lead time advantages as a framework for renegotiations.

No.	Brief title	Gaps and references	Contributions to closing gaps
		(Granstrand and Holgersson 2014).	
3	Monopoly spotting	Managing research collaboration contracts in terms of openness and access has not been discussed across fields of industry.	We indicate how the two-by-two matrix from Paper 1 can be used to manage openness and access on a diversified portfolio, as there are few significant differences between industries.
4	Trade Secret Management in SMEs	Establishing and using trade secrets are not differentiated. There is a lack of empirical data on the choices between secrecy and other mechanisms (B. Hall et al. 2014)	We demonstrate empirically that the differentiation is meaningful and that there is a mix of mechanisms.
		Trade secrets are rarely discussed in the open innovation context Bogers et al. (2017); (Hagedoorn and Zobel 2015).	We detail licencing and cluster participation with trade secrets using quantitative data for SMEs
		The baseline for trade secret uses in SMEs is not known when new legislation in the US and the EU is introduced.	We suggest using the rate of licensing trade secrets as a baseline, rather than the perceived importance by managers.
5	Teaching with Threshold Concepts	No framework has been suggested for the teaching of trade secret management	We substantiate threshold concepts as a useful framework.

Table 2 Gaps and contributions

1.1.3 Thesis – cover essay and papers

The thesis has two parts, first a cover essay and then five papers, as listed in Table 1. This introduction to the cover essay starts by discussing the concepts that I use in the thesis. Then I present the co-authors of the papers and the scope of the thesis, before the theoretical framework. I include my motivation for studying trade secret management as an introduction to the research design and methods. The cover essay further presents the research goal for the thesis and the research questions for each paper. Then follows a presentation of the theoretical framework, the research design and methods, a discussion of each level of the study, including the papers and finally, conclusion and implications.

1.1.4 Concepts –secrecy, trade secrets and appropriation

Trade secrets are a form of secrets relevant to commerce. A secret can have more forms, like being both an academic secret, research results that are kept confidential before publishing, and a trade secret, as the same result is part of a patent application. There are legal definitions of trade secrets, with differences between countries in both scope and process. The differences can be subtle when it comes to the definitions and scope, but as an example, some countries

> **"Every IPR starts with a secret.** *Writers do not disclose the plot they are working on (a future copyright), car makers do not circulate the first sketches of a new model (a future design), companies do not reveal the preliminary results of their technological experiments (a future patent), companies hold on to the information relating to the launch of a new branded product (a future trade mark), etc.*
> *In legal terminology, information that is kept confidential in order to preserve competitive gains is referred to as "trade secrets", "undisclosed information", "business confidential information" or "secret know-how". Business and academia sometimes use other name tags for it such as "proprietary know-how" or "proprietary technology"."*
> (European Commission 2013b, 2)

Figure 1 A quote from the EU Commission that illustrates the many overlapping terms have more openness in the court system than others. The consequence is that in some countries (not in the EU/EEA and the USA) if a firm sues a former employee for revealing a trade secret to a new employer, the trade secret will be disclosed in public during the court proceedings (Lippoldt and Schultz 2014; EUIPO 2018).

The quote in Figure 1 is from the explanatory memorandum of the EU proposal for a directive on trade secrets. The memorandum underlines the importance of harmonisation of trade secret legislation for innovation. The quote shows the lack of a harmonised vocabulary, in that six different terms are listed. Furthermore, the title of the proposal has three different terms: “trade secrets”, “undisclosed know-how” and “undisclosed business information”. That is a total of eight overlapping terms within the two first pages of the EU proposal. It is possible to draw Venn-diagrams, but that is outside the scope of this thesis.

As an example of a legal definition, the EU/EEA definition, that also will apply in Norway, is in Figure 2. There are many questions for legal research, and not for this thesis, in the definition. For example, what are the limitations of “reasonable steps” and “readily accessible”? There are types of trade secrets, but no firm typology. There is a differentiation between technological and commercial trade secrets (European Commission 2013c); but should misappropriation be judged differently?

There are more confusing terms, like "lead time advantages", that is extensively discussed in this thesis in Paper 2. Thus, an early ambition was to present an ontology for trade secret management, that would include definitions for both trade secrets and such related terms. As I gradually understood that even the seemingly opposite term to secrecy, "openness", did not have a clear definition in the research literature, I reduced my ambitions. However, in Paper 1 in this thesis, we contribute to such an ontology and promote a clear distinction between openness and access to knowledge (Knut J Egelie et al. 2019). In Paper 4 we clarify the distinction between establishing and using a trade secret, that is important for management, but not so for jurisprudence, and thus not a part of the legal definitions.

The definition of "trade secret" in EU/EEA:

(1) 'trade secret' means information which meets all of the following requirements: (a) it is secret in the sense that it is not, as a body or in the precise configuration and assembly of its components, generally known among or readily accessible to persons within the circles that normally deal with the kind of information in question;

(b) it has commercial value because it is secret;

(c) it has been subject to reasonable steps under the circumstances, by the person lawfully in control of the information, to keep it secret;… (European Commission 2016)

Figure 2 A legal definition of trade secret

In papers 1,2 and 3 we use the term confidentiality as a variable name. The term is synonymously used with secrecy but has a connotation of shared secrecy. As a trade secret is meant for trade, then collaboration or sharing is etymologically implied, as for confidentiality. In legal terms "confidentiality" is often the name of the clause that defines the parties rights to require secrecy from the other parties.

Having provided a definition for trade secrets in Figure 2, and discussed the term, I still need to define the more fundamental terms of secret and secrecy. A general definition adapted from the sociologist Georg Simmel is “the intentional or unintentional concealment of information”. The context is his discussion on a sociological characteristic of secrecy, with marriage as an example where “*…the secret of the one party is to a certain extent recognized by the other, and the intentionally or unintentionally concealed is intentionally or unintentionally respected*” (Simmel 1906, 462). As this thesis concerns trade secrets in collaborations and open innovation, that definition is suitable: Information is concealed by intention or unintentionally and a collaborator knows there are secrets and respects the concealment. If the concealment is not respected, then there is misappropriation or theft of the secret. Bok (1989) describes secrecy in forms of four attributes: Privacy, Property, Plans and Actions. The attributes add to Simmel’s definition, in that secrecy is related to four human emotions and activities: We guard our privacy, the intimate. Personal secrets are of course private, but so can trade secrets be as well. A firm could consider their trade secrets to be the very soul of the company, as Coca Cola or WD-40 do with their recipes (Crittenden, Crittenden, and Pierpont 2015). Simply, the property aspect of a secret is how we consider a secret belonging to someone.[3] Plans are the reasoning behind keeping the secret, and there is usually an intention. Actions are what is done with the secret, like sharing it or revealing it. All these attributes of secrecy apply to trade secrets as well.

Maret (2016) problematises secrecy and frames it as “*a compelling social problem*”. The background is the secrecy that is unjustified in government, for example, connected to violations of human rights or unethical business such as revealed in the Panama papers. In Paper 5, we discuss how the EU directive on trade secrets explicitly exempts, for example, whistle-blowers from trade secret legislation. In general, this

[3] Interestingly jurisprudence repeatedly discuss whether trade secrets can be considered intellectual property or not (Lemley 2008). The arguments have no bearing on the discussion here and belongs to the philosophy of law. For all practical purposes the EU definition in Figure 2 define trade secrets as intellectual property that can be owned and licensed, even if the EU directive contradicts this.

thesis considers trade secrets not as a problem, but as an option for a business to create and secure competitive advantages.

Securing, or appropriating, or controlling, or governing innovation are terms that are used interchangeably in the literature and in this thesis. "Appropriability of innovation" and "appropriation mechanisms" developed in the late 50ies and early 60ies, for example, in Arrow (1962), who discusses resource allocation for invention. In a market economy, he explains that information may become a commodity that can be appropriated but will spread, for example, by workforce mobility. He continues that "*Legally imposed property rights can provide only a partial barrier, since there are obviously enormous difficulties in defining in any sharp way an item of information and differentiating it from other similar sounding items*." This problem is to the core of the EU definition of trade secrets in Figure 2, and the "*reasonable steps*" that must be taken to protect "*a secret as a body or in the precise configuration and assembly of its components".*

Thus, the legal definition of trade secrets hides management issues concnerning appropriability of innovation, that has been looming behind all research on innovation appropriation since the term was coined. Sun and Zhai (2018) do a scientometric

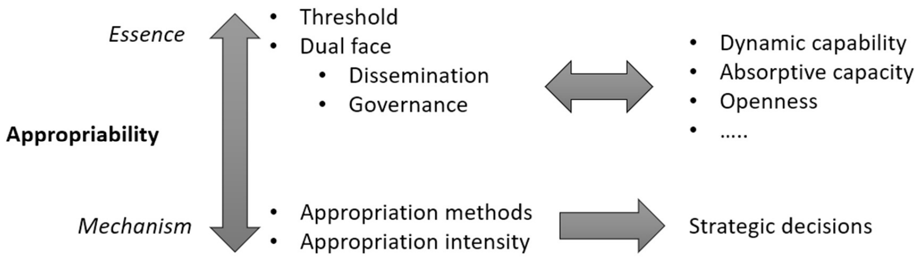

Figure 3 Core aspects of appropriability adapted from Sun and Zhai (2018).

review of all appropriability research in the last thirty years.

In Figure 3, their main findings are summarised in that appropriability research addresses either the essence or the mechanisms. The essence is a threshold effect in that there is a minimum level that is needed for firms to invest in innovation, and then a dual face of governance of the innovation as well as its dissemination. This essence interacts with other concepts from innovation studies such as openness, dynamic capabilities and absorptive capacity (Laursen and Salter 2006; Laursen and Salter 2014; Teece, Pisano, and Shuen 1997). Dissemination that implies publication or revealing is from this figure also to the essence of appropriability. Sofka, de Faria, and Shehu (2018), for example discuss how legal requirements to reveal information interact with the management of trade secrets. They postulate that *"secrecy is more important for protecting knowledge for firms that have legal requirements to reveal information to shareholders".*

The lower part of Figure 3 is the mechanism for appropriation, that has specific methods and intensity. Methods are the appropriation mechanisms that this thesis discusses, mostly in Paper 2. The intensity is for example if a firm depends on one patent application or prepare a portfolio of rights to govern the innovation. The arrow that points to strategic decisions is the same decisions that are listed in Figure 8.

There are no simple definitions or consistent use of the terms secrecy, trade secrets and appropriation of innovation – and in that connection dissemination and revealing. If secrecy is defined as concealment of information, then trade secrets are business-related concealed information. If so, then as a concept "appropriation of innovation by trade secrets" is controlling innovation by concealed information, as all innovation is business-related. However, as discussed in Paper 2, also academic secrets can influence collaborative innovation – and a revealing strategy as discussed by Alexy, George, and Salter (2013) is a part of trade secret management.

1.1.5 Concepts – collaborations and open innovation

The title of the theses, as well as the primary research question, concern both collaborations and open innovation. The distinction is between levels. Open innovation implies collaboration between firms and organisations. However, there may be open innovation without collaboration at a team level. Paper 4 presents findings on how

SMEs use trade secrets when engaging in open innovation. In collaborative research projects, as in papers 1, 2 and 3, the collaborations are at a personal level between research project members from different organisations. Even if the project is structured with sub-projects and deliveries, there is human interaction. Open innovation may take place without such collaboration. It is simply the utilisation of "*external innovations internally, and externally commercializing internal innovations*" (West and Bogers 2017, 43). I do not problematise the term open innovation further, but note that West and Bogers (2017) calls collaborative innovation for "coupled mode of open innovation", and has an extensive discussion of the term, connotations and research literature.

Katz and Martin (1997) discuss research collaborations in detail and show how collaborations can be internal or external, and how the term comprises individuals, groups, institutions, and nations. Collaborations, thus, may take place within all the levels I discuss in section 4.2. Persons and teams collaborate in innovation, as do firms. Even nations and systems collaborate, such as through WIPO and WTO. As an example, the Norwegian Industrial Property Office (NIPO, also known as Patentstyret) collaborates with the European Patent Office and other patent offices through WIPO arrangements in keeping trade secrets. A patent application filed in one country is kept as a trade secret by all other administrations for an agreed period (WIPO 2008, 406). I do not explore this system-level collaboration further, see section 4.2.

The collaboration between individuals in teams is of interest to trade secret management because trade secrets are shared between persons involved in innovation and because trust is built on an individual level. Trade secrets can be lost through interaction with others, or if a team member leaves for another team or firm. Workforce mobility is a known problem for keeping trade secrets but is framed in different ways. Møen (2005) and other economists call such knowledge transfer for spillovers (Audretsch and Keilbach 2005). The national labour legislations set different limitations on to what extent an employee can be denied leaving for a new, competing employer. A firm must balance these rights with their management of trade secrets and their procedures for informing the employees (Delerue and Lejeune 2010; D.R Hannah 2007). Collaborations in teams are of interest because innovation often is organised in projects, and project managers tend to frame the workforce in the project as a team (Tomala and Sénéchal 2004; Edmondson and Harvey 2018).

1.2 *Co-authors and their contributions*

There are five papers included in the second part of this thesis. I introduce the structure of the thesis in more detail later in section 1.3, in addition to a suggested sequence for reading. Below, in Table 3 is an overview of the papers, with an indication of the field of study, the methods and the status for publication.

No.	Title and authors	Fields	Methods	Status
1	Access and openness in biotechnology research collaborations between universities and industry Egelie KJ, Lie HT, Grimpe C, Sørheim R	Innovation studies, Biotechnology	Inductive, mixed methods (quantitative, qualitative)	Published in Nature Biotechnology The early version presented at DRUID18
2	A New Advantage: Trade Secrets, Academic Secrets and Lead Time Advantages in Collaborative Research between Universities and Industry Lie HT, Egelie KJ	Management science, Innovation studies	Abductive, mixed methods (quantitative, qualitative)	Under revision for AoM Discoveries Presented at DRUID19. Parts presented at EPIP2018.
3	Monopoly spotting – an empirical study of research collaborations between universities and industry Lie HT, Egelie KJ, Grimpe C, Sørheim R	Innovation studies, Management science.	Inductive, mixed methods (quantitative, qualitative)	Accepted for the AOM annual meeting 2020. Journal to be decided.
4	Trade Secret Management in SMEs Lie HT, Tobro M, Hansen TB	Innovation studies, Management science	Inductive, quantitative	Submitted to Journal of Small Business Management Presented at EPIP2019
5	Teaching Trade Secret Management with Threshold Concepts Lie HT, Hokstad LM, O'Connell D	Educational science, sociology	Decoding of disciplines	In second revision for "Secrecy and Society" Special Issue on the Challenges of Teaching Secrecy

Table 3 List of papers with authors, field, methods and status

Table 4 lists the contribution from each co-author of the paper. All co-authors have contributed to drafting, commented, and approved the version submitted or published. The table reflects the formal requirements for submitting the thesis.

Paper	Co-authors	Affiliations	Contribution
All	All		All co-authors have contributed to the conception and design of the papers. They have contributed to the drafting, read and commented, and approved the version submitted or published.
1	Knut Jørgen Egelie	NTNU TTO AS; NTNU, Department of Biology; CIP- Center for Intellectual Property	Egelie was first author, a co-investigator and scoring around half of the contracts. As a biologist, he provided the CRISPR background for the project and the biology-related references. From his TTO-background he contributed with the initial scoring model and the resulting matrix. The paper is also part of his PhD-thesis: (Knut Jørgen Egelie 2019).
1	Haakon Thue Lie	Leogriff AS; NTNU, Department of Industrial Economics and Technology Management; CIP- Center for Intellectual Property	I was the second author and investigator, scoring around half of the contracts. I contributed to the ontology behind the scoring model and matrix, wrote the anonymised cases, and did much of the writing.
1	Christoph Grimpe	Professor at Copenhagen Business School, Department of Innovation and Organizational Economics	Grimpe guided the analytical work and did most of the analysis in Stata. He contributed to the theory part and especially in the finalisation of the two-by-two matrix.
1	Roger Sørheim	Supervisor, professor at NTNU, Department of Industrial Economics and Technology Management	Sørheim supervised the project. He worked on the introduction part, focussing the paper and the frame of reference, connecting the work to the literature on university-industry collaborations and innovation.
2	Haakon Thue Lie		I am the first author, writing the main part of the paper. I presented the draft at DRUID19. The dataset is as for paper 1; however I created new codes and then re-coded the subset of 52 projects, working with Egelie. I used Nvivo and SPSS for analyses.

2	Knut Jørgen Egelie		Egelie scored the dataset as for paper 1 and helped with the re-coding. He contributed to the writing and the discussions on the concepts.
3	Haakon Thue Lie		I am the first author. The contribution is similar as for paper 1.
3	Knut Jørgen Egelie		The contribution is similar as for paper 1.
3	Christoph Grimpe		The contribution is similar as for paper 1.
3	Roger Sørheim		The contribution is similar as for paper 1.
4	Haakon Thue Lie		I wrote most of the paper. I created all questions concerning secrecy and IP procedures in the survey, and collaborated with Hansen on the other questions and on the structure, see (Hansen, Lie, and Vestergaard 2014).
4	Anne Marte Lunde Tobro	Industrial PhD-candidate with Innovation Norway and the University of Oslo, Department of Economics.	Tobro contributed to all workshops, worked on the empirical part and did the regression analyses in Stata.
4	Tor Borgar Hansen	Senior analyst with Oxford Research and associate professor at University of Oslo, Department of Informatics, Digitization and Entrepreneurship	Hansen was project manager for the 2013 research project, set up the survey and conducted the e-mailing and collection of answers, as per (Hansen, Lie, and Vestergaard 2014). He participated in the initial workshops setting directions for the work.
5	Haakon Thue Lie		I am the first author, edited all contributions and did the initial analysis of counterintuitivity.
5	Leif Martin Hokstad	Professor NTNU, Department of Education and Lifelong Learning	Hokstad contributed with the educational science part, including the research method and the framework of threshold concepts.
5	Donal O'Connell	Visiting researcher of IP at Imperial College Business School.	O'Connell contributed with cases, the exemptions from trade secret legislation and with parts of the curriculum.

Table 4 List of contributions to the papers

1.3 *Outline of the thesis*

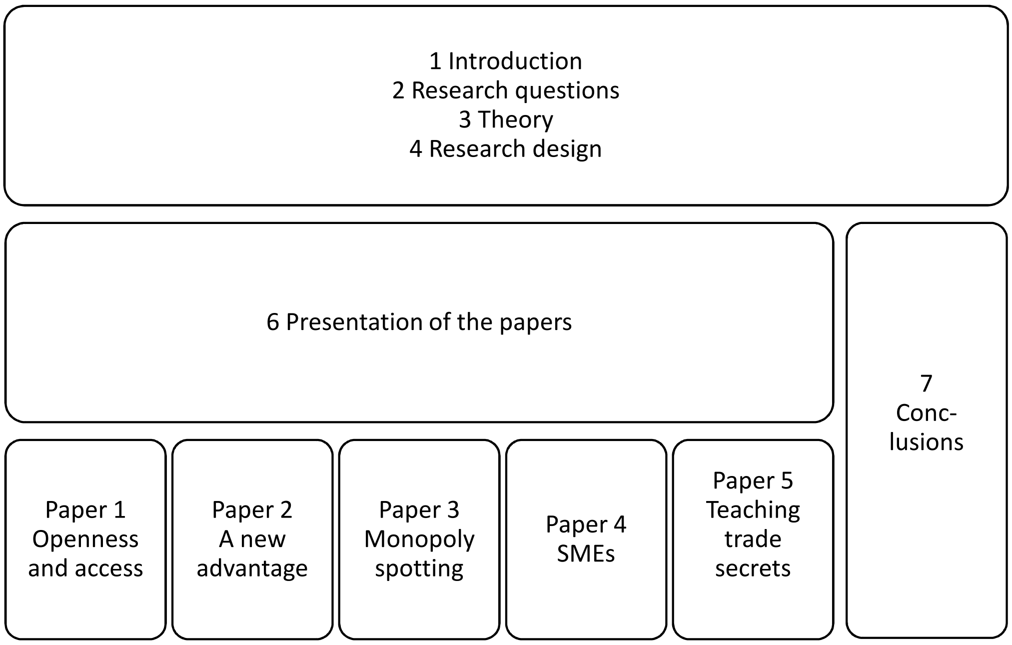

Figure 4 The chapters and papers in the thesis

An outline of the thesis is in Figure 4. Paper 1 is a good entry point from an innovation studies perspective- It belongs together with Papers 2 and 3, in the discussion of openness, access and collaborative research. Paper 5, however, is more connected to sociology and epistemology, and could also be a good entry point for reading the papers. Paper 4 connects with open science and the procedures in firms and could also be read first.

2 The research questions

2.1 *Research question for the thesis*

The broad research question for the thesis is:

- How are trade secrets managed in collaborations and open innovation?

The question was formed by the initial motivation to be discussed in section 4.1, by reflecting over the gaps in the literature as discussed in section 1.1.2, while I started with how Alvesson and Sandberg (2011) discuss problematisation as a way of generating research questions. Their methodology points away from using a gap in the literature as the starting point, but rather a dialectical interrogation of the position well known to oneself, as well as the literature. The research question has these qualities. First, there is an inherent dialectic in the Hegelian sense between secrets and open innovation. This contradiction, as explored in Papers 1 to 4 or even counterintuitivity as in Paper 5, results in clear syntheses in Paper 1, Paper 2 and Paper 5, in the form of new methods pointing towards tools. Secondly, the dialectics is hidden within the term "trade secrets" itself. Trade implies collaboration, as discussed in section 1.1.4. Further, in the field of innovation studies, the concept of "appropriation mechanisms" hides the underlying importance of control over knowledge by secrecy. The literature discusses trade secrets but somehow misses out how trade secrets can be managed for knowledge sharing, and thus be a part of engagement in collaborations or open innovation.

2.2 *Main research questions for each paper*

The broad question of trade secret management in collaborations and open innovation are depicted in Figure 5. The central question is encircled by

- How is the societal utility of collaborative research results affected by the governance of secrecy and openness? (Papers 1 and 3)
- How can universities and industry agree on secrecy in collaborative innovation? (Paper 2)

– What characterises firms' establishment and use of trade secrets, in terms of management procedures and possible engagement in open innovation? (Paper 4)
– How is a curriculum for teaching trade secret management at master-level or to managers? (Paper 5)

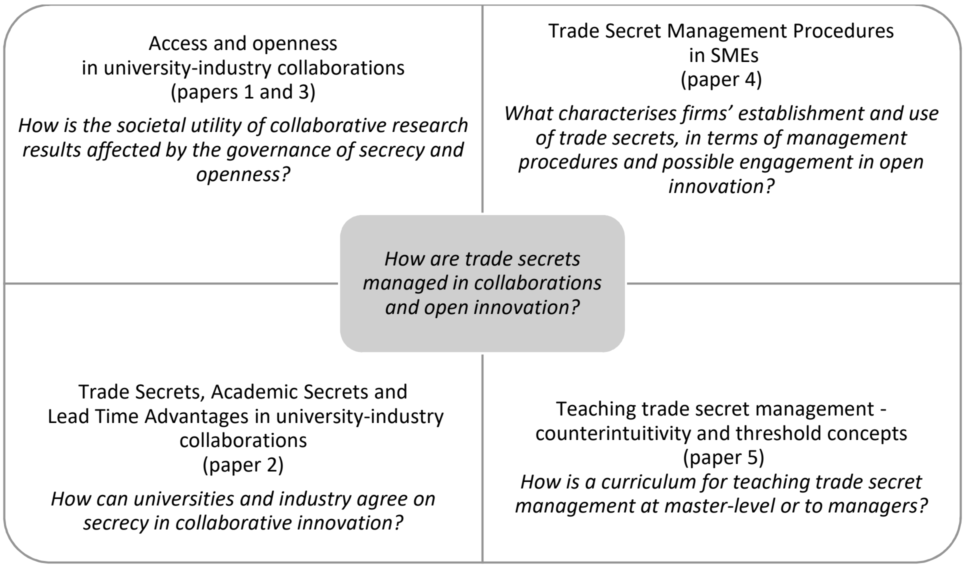

Figure 5 The main research question and research questions of the papers

These research questions are synthesised from the papers. The research question is, for example, not evident in the published paper 1; however, the research objective is distinctive. I discuss the verbatim research questions or objectives in the papers in chapter 5. There is also a mentioning of the research design and the main contributions from each paper that answers the questions, see more details in chapter 4 and section 6.3. There are epistemological and ontological objectives for this thesis. I discuss these in sections 4.5 and 4.5.

3 Frame of reference

3.1 Applied law and trade secret management

Secrecy does not depend on the law. If innovation is successfully appropriated using trade secrets, then there is no need for a law or lawyers. However, the law comes useful, for example, in that it allows a contractual limitation on a buyer's or licensee's right to reverse engineering. Also, EU and Norwegian law on trade secrets allow the owner of a trade secret to sue a third party for trade secret misappropriation.[4] Thus, the legislation that concerns trade secrets is valuable whenever trade secrets are to be used in knowledge exchange, including when informing co-workers. As discussed in section 1.1.4 Concepts –secrecy, there are legal definitions of trade secrets. The laws in the EU and Norway, as well as in other countries have evolved for over 100 years. They are mostly national variants of the Paris convention's rules from 1900 on the principle of unfair competition (Bodenhausen 1968).[5] However, the new laws in the EU and the USA align trade secrets with intellectual property, in that the trade secret is regarded as an object, that for example can be licensed. The legal literature on trade secrets is plentiful. There are works from the philosophy of law and comparative law that investigate fundamental issues of trade secrets. A line of American legal researchers discusses the Arrow's information paradox from economics. Arrow (1962) explained how someone in the process of buying information, could run away without paying for it if the information was disclosed before the payment was received by the seller. Aside from escrow agreements, patents solve this paradox. The patent holder can deny anyone to use the technology. A licence for the information in the form of a trade secret also solves the paradox, as the legislation allows the seller to sue the buyer for

[4] The term misappropriation is used rather than "theft", as the misappropriator usually got the secret from someone sharing it voluntarily. As appropriation is used for governance of innovation, there could be misperceptions.

[5] The Paris Convention is from 1884. In 1900 a revision introduced article 10bis on unfair competition. Trade secret misappropriation is one such form of unfair competition. Others are passing-off and counterfeit. Later trade agreements, such as the Trade-Related Aspects of Intellectual Property Rights (TRIPs) have more details on trade secrets.

misappropriation. Thus, a critique of the assumed paradox is that real licensing and technology transfer is not homogenous. The information for sale is complicated and assembled and many forms of appropriation and dynamic capabilities solve the Arrow information paradox. There are arguments on how trade secrets solve the paradox so well that trade secret law could in the future replace the patent system (Bambauer 2015; Burstein 2012; Reichman 2011; Lemley 2008).

This view from legal theory, that trade secrets in combination with other rights form a portfolio of mechanisms that allows governance of innovation and thus, collaboration and open innovation are what all papers in this thesis reflect. Further, Levine and Sichelman (2018, 14) explain how information concerning secrecy can be layered. Parts of the information can be kept secrets for a longer time, and thus mediate the Arrow information paradox. This layering implies that information need not be either secret or open; there may be intermediate positions that evolve.

With this ability to appropriate and control innovation, also comes the need for balancing secrecy and openness. This balancing act is delicate because it holds both proprietary controls enforced by the law, and on the other side, holds the freedom of knowledge commons and imitation. Also, the details of the law vary between countries (Caenegem 2014, 11-18). The legal regime has effects on innovation. Looking at the introduction of new trade secret legislation in the USA, Png (2017) reports an association with increased research and development in some industries, including pharmaceuticals and computers. There is a positive association between firm value and the legal protection of trade secrets in industries with high mobility of knowledge workers, (Castellaneta, Conti, and Kacperczyk 2017).

Typical topics for the legal research that concerns trade secret management are the need for audits, non-disclosure agreements, workforce mobility, informing the employees and the rising need for legislation regarding cybersecurity (Epstein and Levi 1988; Pooley 1982). This line of legal research is now centred around the recent changes in European and American legislation on trade secrets and the consequences for litigation preparation and management (Levine and Seaman 2018; M.F Schultz and Lippoldt 2018; EUIPO 2018).

3.2 *Trade secrets' particular need for management from day one*

Trade secrets are the only appropriation mechanism where the object of appropriation cannot be published. The consequence is that management is needed from the first day the secret knowledge comes into existence. The secret must be kept secret and delimited. Management of a secret requires metadata. In brief, several characteristics must be set for the secrets, such as who is in the know, what measures protect it and the likely duration and combinations with other mechanisms.[6]

The metadata enables management of the trade secret without the manager having to be in the know. It is possible to count and enumerate the trade secrets of a firm, and connect them to the innovations, and do license agreements, without disclosing the secret itself (E.M. Lee and May 2016).

3.3 *Trade secrets and the role of the intellectual property manager*

Intellectual property (IP) management was first developed as a field in large Japanese corporations. The management function developed from being treated as a distributed, low management task to have the attention of top management and be organised accordingly (Granstrand 2000, 7). In both Western and Asian firms, the function of IP management and the role of an IP manager is now widespread and accepted (Carlsson et al. 2008; Al-Aali and Teece 2013). For universities, the importance of IP management increased after the US Bayh-Dole law changed how universities commercialise research (Grimaldi et al. 2011).[7] Most universities now have a Technology Transfer Office or the similar, where there will be IP managers (Holgersson and Aaboen 2019).

[6] These are reflected the mid column in Figure 8.

[7] Both co-author of Papers 1, 2 and 3 Knut Jørgen Egelie and I are IP managers by profession.

The IP manager's field of work is reflected in Figure 8, later in the sections on research method. The IP manager translate or mediates from the social, relational sphere to the institutional sphere, and operates on all levels: On the individual level IP managers discuss with inventors, designers, programmers and other roles, and facilitates how the organisation takes ownership of the knowledge of the individual, such as a trade secrets or research results. On an organisation level, most IP managers now contribute to the strategy processes. Also, an IP manager relies on and must know in detail the working of the global IP system for patents, copyright, trademarks and designs, and other rights, facilitated by United Nations through the World Intellectual Property Organization (WIPO). The role of the IP manager can be combined with other roles in an organisation, such as the roles of research manager, knowledge manager, quality manager or legal counsel. The role can also be distributed or outsourced (Tomala and Sénéchal 2004; Gargate and Momaya 2018; Carlsson et al. 2008).

3.4 *The organisation and workflow*

(Bos, Broekhuizen, and de Faria 2015) presents a model of the usual process or cycle of trade secret management in an organisation. They introduce a three-stage model that comprise protection strategy, preventive measures, how to protect and exploit a secret, and ways to deal with contingencies. The model divides the management issues into areas where decisions can be taken and reflect the way many firms manage trade secrets. However, the model lacks the effects of a revealing strategy, as discussed in (Alexy, George, and Salter 2013), but assumes that disclosure is through leakages. Also, the model lacks

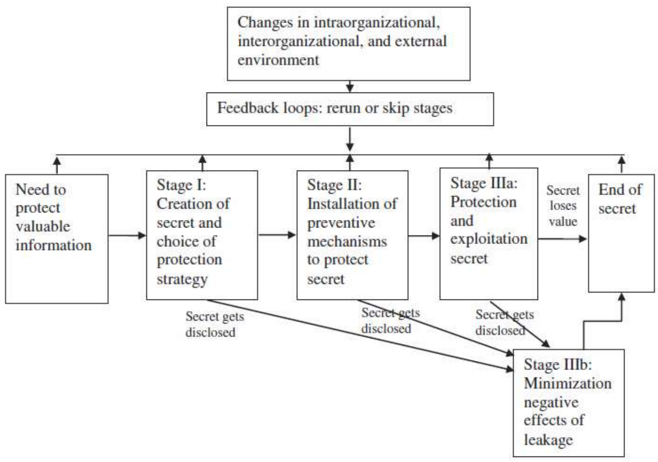

Figure 6 Secrecy management cycle according to (Bos, Broekhuizen, and de Faria 2015).

interaction with other types of appropriation, as discussed by (Hurmelinna-Laukkanen and Puumalainen 2007). Nevertheless, Figure 6 serves as a useful reference model for discussion trade secret management in isolation. An insight is from an empirical study of biotech SMEs. Delerue and Lejeune (2011) underline the importance of the organisations' management of trade secrets, is that the legal framework may not be pivotal to the extent organisations use trade secrets, but rather the institutional environment and informal aspects.

How to encourage loyalty and trust between employer and employee, and between researcher and business partner, is a part of the management of trade secrets, and will include rules (D. R Hannah and Robertson 2015). A model for trade secret management that builds on rule-following and use the climate metaphor is in (Robertson, Hannah, and Lautsch 2015), as shown in Figure 7. The model shows, for example, that clear communication about the procedures for handling trade secrets will influence the climate positively, whereas occupational values – such as those for programmers or researcher – may influence the climate negatively. Among positive effects is the preservation of competitive advantage, and an adverse effect is on the sharing of knowledge. The individual's relation to trade secrets will be complicated from the conflict between privacy and property, as persons will see knowledge and secrets as an individual attribute (Dulipovici and Baskerville 2007).

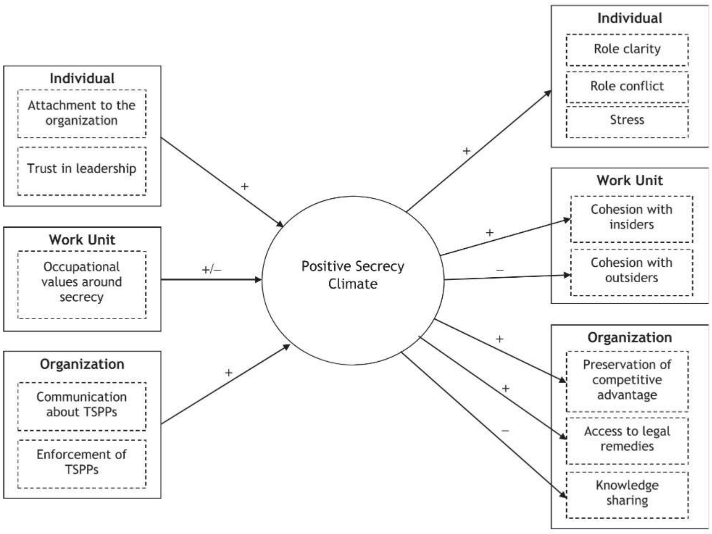

Figure 7 The model from (Robertson, Hannah, & Lautsch, 2015) p672. TSPP is an abbreviation for Trade Secret Protection Procedures

The organisational and societal view develops from the work of Georg Simmel on secrecy and secret societies (Simmel 1906). There focus is on secrets in general and not on their function in innovation (Marx and Muschert 2009, 13). Grey and Costas (2016) propose "organisational secrecy" as a part of organisational studies, with an emphasis on secrecy being normal human behaviour and an integrated part of any organisation. The procedures in an organisation for managing trade secrets, and to what extent the employees follow these have been studied the last decade (David Hannah 2005; D.R Hannah 2007; D. R Hannah and Robertson 2015; Robertson, Hannah, and Lautsch 2015). There are also studies concerning professions with norms that oppose secrecy, such as researchers and programmers (Nelson 2016; Feldman 2006; Petrusson 2016). As business information more and more is digitally stored and transferred, cybersecurity becomes an integral part of trade secret management. Recent research explores and discusses how widespread sharing of knowledge affects confidentiality and related issues such as privacy. As the networks become more complex, embedded into the organisations with machine learning and artificial intelligence included, the management of trade secrets cannot be seen isolated from the management of the firms' relations, R&D and production capacities (Villasenor 2015; Rowe 2016; Goyal, Mehta, and Srinivasan 2017; Ilvonen et al. 2018; Lezzi, Lazoi, and Corallo 2018).

3.5 Publications, appropriation and dominant design

A publication, like an article in a scientific paper, a conference presentation or a patent publication, influences appropriability: A technology cannot be patented if it is published.[8] Publication or strategic disclosure of an invention will make it impossible for others to patent the same or a similar invention. Unless there are other appropriation mechanisms in use, the publication will allow others to copy. For a researcher or a software developer, priority and possible fame is secured. For commercialisation, the publication may contribute to "freedom to operate", that there

[8] There is a one-year grace period in the USA. A publication will also hinder design registrations in e.g. China and Australia.

are no others that control the technology. The revealing strategy is important, as a publication will hinder own patenting and not only that of the competitors (S.J. Graham 2004; Bok 1982). When innovation is or will be appropriated, then it is possible to negotiate the ownership. If knowledge is published, for example in a scientific publication, and there is no appropriation of the knowledge, then there is no ownership – the knowledge becomes free for all to use.[9] However, knowledge can be shared within the collaboration in the form of trade secrets and then later as the project ends, there may be a combination of technical knowledge that is appropriated by for example patents, and by trade secrets. The parties can now discuss how the results should be disseminated and utilised. The problem is that this discussion is guided by the assumptions and agreement made when the project was established, and the parties had little or no information about the results. The renegotiation between the parties will then, for example, take place in the form of follow-up projects. Granstrand and Holgersson (2014) theoretically discuss this as "closing open innovation" or as intellectual property disassembly and reassembly.

In a later phase of innovation, the concept of dominant design will influence the revealing strategy. The dominant design is a de-facto standardisation, such as where the wheel and pedals are in a car, or the graphical interface of computers with a desktop metaphor. The concept connects with the appropriability regime (Srinivasan, Lilien, and Rangaswamy 2006). Trade secrets will be lost, as the dominant design emerges through imitation, parallel development and reverse engineering. These are processes of technological change that creates new technological paradigms and platforms (Utterback and Suárez 1993; Dosi 1982). Mansfield (1985) points to how technological trade secrets last in average 12 to 18 months. However, commercial trade secrets, such as those needed for marketing and sales, may last much longer.

[9] The copyright to a scientific publication gives no ownership to the knowledge, only to the verbatim text and presentation of the results.

Both types of secrecy are regarded as equally important (European Commission 2013c, 135,136)

3.6 Secrecy in research and how it affects collaborative innovation

3.6.1 Pasteur's quadrant and trade secrets

Stokes (1997, 73 Fig. 3-5) divides research into the three quadrants that answers "yes" to the questions "Quest for fundamental understanding?" or "Consideration of use?". The quadrants are named after famous scientists and their stereotyped contributions to research. The Pasteur quadrant if for research that is both fundamental and has considerations of use. The Bohr quadrant is for "Pure, basic research" and the Edison one for "Pure, applied research". The model challenges the view that science is either "pure", i.e. basic, or "applied", i.e. commercial exploitation of the technology coming from the basic research. Further, Stokes argues that knowledge from research can be put to immediate use. There is no necessity in a knowledge transfer from basic to applied research, as some scientists, like Pasteur, can consider use while performing applied research.

In terms of secrecy, that is not discussed by Stokes, the model is also interesting. For the pure basic research, one could argue that there are no trade secrets, as the knowledge is not "business-related", nor does it have "value for business from being kept as a secret". In other words, The Bohr quadrant research has no apparent commercial value. If Bohr kept secrets, they were academic secrets to secure his priority in publications or military secrets related to the development of the atomic bomb. Edison, whos quadrant is for the pure, applied science, had trade secrets, did reverse engineering and was involved in industrial espionage (Bilton 2004).

Pasteur should from this model then have both academic and trade secrets. Pasteur was heavily criticised for keeping secret details of his research on anthrax and rabies. In the development of anthrax and chicken cholera vaccines, there is a fascinating mix of academic secrets in a fight for priority, as well as commercial considerations resulting in trade secrets on vaccine production (Geison 2014, 47, 145-176, 226).

Pasteur's legacy is then both in line with how Biagioli (2012) explains that scientists keep secrets to reduce the risk of losing priority, as well as with Bok (1982) who discuss the ethics of secrecy in research, in particular in the medical field. She argues that "*…special constraints are needed and legitimate in science, over and above the more general caution that trade secrecy should always inspire."* This argument builds on a discussion on the many adverse effects secrecy can have, and how scientists funded by society have a special duty to ensure the free flow of information. However, she notes that trade secrets may be required to facilitate the utilisation of the research. Pasteur and all researchers in that quadrant face the same dilemmas: How to keep scientific priority and how to best utilise the research results for the benefit of the society. In many cases, secrecy can an answer.

3.6.2 Renouncing Merton – Philosophy of science and secrecy

Perkmann et al. (2013, 433) discuss how academic science is diverse and how the Mertonian norms [for this thesis, in particular, the norm of "communism" (Merton 1973, 273-275)] cannot be used as a discreet characterisation of all academic institutions. Perkmann et al. conclude that *"An important objective for future research is … to question the pervasiveness and purity of the Mertonian norms, and shed light on the … diverse patterns of university-society interactions …".*

Merton states on this norm that *"Secrecy is the antithesis of this norm; full and open communication its enactment"* (Merton 1973, 274). He builds on Bernal (1939, 59, 107) that discuss how the industry does not want to perform research in university labs, as the discussion flows too freely there, and secrets can be lost. (Hong and Walsh 2009) explore the tension over secrecy between academia and industry. Their study shows that there is an increase in secrecy in science for the last 30 years. The increase holds for most industries, and in particular for experimental biology. They underline that there is a complicated entrepreneurial relationship between industry and academia. (Czarnitzki, Grimpe, and Toole 2015a) have similar finding is their study of German scientists, in that they show that industry sponsorship of research, reduces the public disclosure of the results.

(Biagioli 2012) discuss “secrecy, openness and priority in science”. His point is that secrecy within academia is risk aversion related to claims of priority. Scientists must publish to establish priority, that they were the first behind the new knowledge. By keeping their research secret, they reduce the risk of others publishing before them. Secrecy in this way applies to all systems of priority, including the patent system, the system of scientific peer-reviewed journals and self-publishing in open depositories.

So, there are two types of secrecy in academia, both seen by Merton as the antithesis of scientific norms:
- Secrecy within academia that follows from the scientific competition.
- Secrecy, in the form of trade secrets, that follows from collaborative research with industry.

However, competition and collaborative research can hardly be viewed as defying scientific norms Bok (1982, 38).points to how scientists ethically can keep trade secrets, but ought to have higher standards for openness than entrepreneurs. Heesen (2017) discusses the intensives to share and how secrecy and priority affect the communist norm. In a game-theoretic model, researchers have incentives to share widely, so normative expectations are not needed to explain why scientists share. The caveat is that the model only works if the publication of intermediate results is credited. The incentive system for researchers then guides the publication of research results and the extent of secrecy amongst researchers.

3.6.3 Tensions between academic and industrial secrecy

As the universities become entrepreneurial, they need to manage trade secrets. The tension is then not only the tension of the handover between non-entrepreneurial universities to industry, from pure to applied research. The tension arises within the university, as it engages in collaborative research, jointly with industry, or as it tries to commercialise research that is in the quadrant of Pasteur. The universities established TTOs (Technology Transfer Offices) as a managerial response to the increased engagement in the commercialisation of technology. The universities have multiple objectives with their licensing and technology transfer. There is partly a motivation for a possible income, and partly a motivation for the utilisation of the research in line with the 1980 Bayh-Dole act in the USA (Thursby and Thursby 2007). This act transferred the ownership of the intellectual property from the publicly-funded granting agencies to the universities. The expectation was that the universities could contribute more directly to industrial development (A.J. Stevens 2004). A result was that the universities in the USA established technology transfer organisations, TTOs, to utilise the intellectual property. Norway followed the same pattern (Bozeman 2000, 24; Knut Jørgen Egelie 2019).

Perkmann and Walsh (2007, 263,table 2) present a typology of university-industry links. Transfer, e.g., licensing of intellectual property is categorised as a low relational involvement. Relationships, e.g., research partnerships, imply high involvement. Open innovation is set in this context of high involvement. IP licencing is low. Regarding the role of secrecy, there is a substantial distinction too, that in the case of IP licensing, the trade secret must be well defined and well documented. In the case of high involvement, there are then two or more parties that must agree on the role of possible secrets, both as part of the background that the parties bring into the research and as part of the possible results.

The funding of the research can be relevant. Joshua S Gans and Murray (2012) discuss how firms may choose not to be sponsored in a collaboration project, to avoid any rules on disclosure. Their findings are that the sponsor must then design the rules for the grants to balance requirements on non-exclusivity and mandatory disclosure with the possibility for industrial participation. Czarnitzki, Grimpe, and Toole (2015a) surveyed the disclosure restrictions in the projects of German researchers sponsored by government, foundations, industry and other sources. They conclude that there is a positive correlation between disclosure restrictions and industry sponsorship. This is in line with previous studies on researcher and managers in life science, that confirm how the collaboration between the firms and universities implied a lower flow of information between academic colleagues (Blumenthal et al. 1996; Blumenthal, Causino, et al. 1996). A later study by Louis et al. (2001) expand on the difference between clinical, i.e. applied, and non-clinical, i.e. more basic, research. Here the most secretive were researchers in non-clinical research. Also, there was more secrecy for projects with higher budgets.

This discussion on the funding and how universities and industry are to handle requirements of secrecy is to the core of the discussion by Etzkowitz (1983, 226-227). His setting is two conferences held between American universities and industry in the early 80ies. The outcome was an understanding that research should be published, though with "certain limitations". Etzkowitz has here an example of a researcher that left for industry and preferred that for the academic freedom it gave. The reason was that in the researcher's field, patenting was important. As the industry has more and better resources available, he would get patent applications filed early. Then the secret would no longer be a trade secret but be protected by the patent application. This appropriation allowed the researcher to publish scientific results. Thus, this procedure secured both academic and intellectual property priority, and he could publish earlier than what a university position may have allowed.[10]

Gulbrandsen and Smeby (2005, 936, 946) expand on what they call the "secrecy problem". They conclude that in their Norwegian study, there are more collaborations, more publications and more entrepreneurial results from professors with industrial funding. Thus, possible requirements for secrecy from the industry do not lead to less academic publishing. The broad literature review of academic engagement in commercialisation by Perkmann et al. (2013) presents no conclusive evidence that industry exposure for researchers leads to increased secrecy and less academic publications.

[10] The interplay between trade secrets and patents is complicated, and during this period from the early 80ies, USA changed the rules for secrecy and the publication of patents (S.J. Graham 2004; S.J. Graham and Hegde 2014).

3.6.4 Academics' engagement with industry

Universities are governed by laws, regulations and funding, aside from their boards and administration. There is a rich literature on university governance and how that relates to their third mission of entrepreneurship and innovation (Perkmann et al. 2013; Sarewitz and Pielke 2007; Lidhard and Petrusson 2012; Petrusson 2016).

Academia's engagement in university-industry relations may have individual discretion as the main determinant (Perkmann et al. 2013, 433). This is interesting when viewed on the background of how knowledge flows and in what channels, that is in what settings or within what frames or concepts the interactions are. The individual attitude to secrecy is then of importance to the knowledge flow in academia.

D'Este and Patel (2007) discuss the channels that the researchers use for interacting with industry. They note that " *… too much attention on patenting and spin-off activities may obscure the presence of other types of university–industry interactions that have a much less visible economic pay-off, but can be equally as (or even more) important both in terms of their frequency and economic impact."* In this study, the types of interaction are grouped in five, where "joint research agreements" is one of them. Joint research participation varies from low (12%) for mathematics and high (63%) for mechanical engineering. Joint research is where intellectual property rights (IPR) are used to regulate the ownership of the results, and the topic of Papers 1, 2 and 3 in this thesis.

Trade secrets are also, as patents are, knowledge closely connected to individuals. The conclusions in Perkmann et al. (2013, 433) on the importance of individual measures, concerning the differences in the channels, suggest that there is a need to understand better how trade secrets are managed with the individual researchers, and not as a general contractual clause in the joint research agreements.

Researchers that are employed in industry, will have the same strong preferences for publication, as their university employed colleagues. Joshua S. Gans, Murray, and Stern (2017, 825) conclude on the individual's role: *"… firms considering disclosure strategies* *must not only understand the degree to which these conditions hold, but also must develop approaches that allow for disclosure of all types to be highly coordinated with their critical employees".* This conclusion builds on a dynamic model that shows how stronger appropriation and races for priority can lead to more openness in commercial science settings. In other words, the balance between secrecy and openness for firms regarding scientific results is a balance based on the engagement of the individual researchers. On an individual level, this is how Bok (1989 Ch X, p12/40) discuss personal autonomy and trade secrets.

Lam (2011, 1364) discuss how what she calls "hybrid scientists" will seek to resolve the tension from secrecy, the cognitive dissonance by "*actively reconstituting the meanings of commercialization better to fit with their self-endorsed values and professional goals.*" The hybrid scientist is a researcher likely to operate in "Pasteur's quadrant", as previously discussed.[11] A conclusion is that "…*given the diverse values and motives underlying scientists' commercial pursuits, it is unlikely that an undifferentiated approach will be effective…".* That is, as the personal agency matters, if the university wants to engage all types of scientists, then inflexible policies will create tensions.

The tension that is present at an individual level is also a factor at the organisational level. University-industry collaboration has tensions between the objectives, motivations and norms of the institutions. In some organisations, the tensions are embedded and become a part of the culture. There is a hybridisation. Research institutes and collaborative research centres are hybrid organisations that try to accommodate both the academic and commercial cultures. Hybridity can be built into both their objectives and their organisation. The hybridity requires a balancing act and may result in instability and resistance within the organisation and towards their partners. If successful, this ability to balance and integrate is very much what is crucial

[11] Lam calls a scientist working more like Edison, as "Entrepreneurial" - I have not worked through the four typologies of Lam and how they may map on the Edison, Bohr and Pasteur concepts.

for “Mode 2” knowledge production (Gulbrandsen 2011; Gulbrandsen et al. 2015; Gibbons 1994).

Research institutes are organisations that are in nature between the universities and industry, and that participate in collaborative research projects with both. Gulbrandsen (2011) discuss these organisations as a hybrid organisation. They have a much higher turnover of researchers, compared to universities. It is also a prerequisite for them to have systems to manage confidentiality (Egelyng 2005). Thus, they are more exposed to breaches of confidentiality, and has fewer possibilities for the appropriation of innovation, due to workforce mobility (Delerue and Lejeune 2010). Also, as a topic for further research, they should have much more acceptable secrecy agreements than universities.

3.6.5 Reproducibility

Reproducibility is essential for understanding how secrecy affects research. Jasny et al. (2017) point to the need for research to be reproducible to have an impact. They present a list of issues that must be explicitly agreed between the parties in industry-academia partnerships. Access to the research data itself is necessary. They point to how even scientific journals have agreed not to make the complete dataset available for other researchers (Jasny et al. 2017, 761). If the agreements between industry and universities do not address reproducibility when agreeing on secrecy, it will mean that impact measures based on publication data will be wrong, as the publicly available research is assumed to be reproducible. Reproducibility is not an explicit issue in collaboration agreement templates (DESCA 2017; The Research Council of Norway 2019). A related question is that of the availability of clinical data. The results of genetic testing are kept as trade secrets in proprietary databases and impede research on genetical diseases, such as forms of cancer (Cook-Deegan et al. 2012).

3.7 Open innovation and the paradox of secrecy

As discussed in section 1.1.5 Concepts – collaborations and open innovation, West and Bogers (2017) have an extensive discussion of the open innovation research literature and connects it to collaborations as well. The broad review of emerging themes in open innovation research by 23 authors in Bogers et al. (2017) does not mention trade secrets. However, the paradox of both sharing and protecting knowledge in collaborations are discussed in (Bogers 2011). Further, Hagedoorn and Zobel (2015) survey 850 firms in Europe and North-America on the role of contracts and intellectual property rights in open innovation. They follow the distinction in Figure 3, that appropriation has both a protection and a signalling effect, that is the "dual face" in the figure. Interestingly, they find that patents are more important for protection, but trade secrets are paradoxically the most critical mechanism for signalling (Hagedoorn and Zobel 2015 table 2). Thus, telling potential open innovation partners that there are trade secrets to be shared enables the mutual engagement in open innovation.

Even if secrecy may intuitively be opposed to openness, there is then in the search strategy for a firm, no conflict between engaging in open innovation and licensing knowledge in the form of trade secrets. Trade secrets are used for signalling and informal knowledge exchange as described by Von Hippel (1987), but also as an object for licensing: Whenever knowledge is licensed, there must be an object for the license.[12] This object, the knowledge may be appropriated by the licensor, for example as a patent or by copyright. However, if the knowledge is not public, as a patent is, then the knowledge is usually in the form of a trade secret or a combination of trade secrets and other rights, for example, copyright. Thus, trade secrets are tools for knowledge exchange and parts of the contracts between firms in open innovation (Manzini and Lazzarotti 2016, 581,582). National and regional innovation systems that have reliable legal protection for trade secrets benefit from more exchange of knowledge. Lippoldt and Schultz (2014) report *"a positive association between the stringency of trade secrets protection and key indicators of innovation and international economic flows."* Start-ups (that are assumed mostly to be SMEs) view trade secrets differently than large companies. Where revenue from licensing is more

[12] The reasons are to avoid money laundring and for antitrust purposes, see for example https://ec.europa.eu/competition/antitrust/legislation/transfer.html

important than from product sales, secrecy is more used (Levine and Sichelman 2018 IV C).

The framework of "Profiting from Innovation" (Teece 1986, 2006, 2018b; Pisano 2006) includes appropriation as a core concept with trade secrets - from the initial models in 1986 to the recent discussions in 2018 on the digital economy. The framework is much cited in the open innovation literature (Dahlander and Gann 2010; Bogers et al. 2017). Appleyard and Chesbrough (2016) build on Chesbrough's models and shows how the openness strategy can change ex-ante and ex-post of innovation projects. Secrecy and closed strategies are not dichotomous to openness, but a strategy that can be used dynamically with openness.

Other researchers also point to this dynamic in open innovation. Laursen and Salter (2014) discuss the managerial choices and how the strength of the appropriability strategy is connected to the relationship to external actors in the innovation system, that is the engagement in open innovation. An exciting example is for crowdsourcing at the individual level and with outbound open innovation. Here single researchers work on projects and will switch between openness and secrecy, and formal and informal agreements (Foege et al. 2019). Further, Costas and Grey (2016, 1) begin their analysis of how organisations use secrecy with stating: "*…being omnipresent, secrecy creates a social order, for example, by establishing boundaries between insiders and outsiders."* By sharing secrets, the parties collaborating in an open innovation project whether individuals or organisations, all become insiders.

Van Overwalle (2010) concludes on the interaction between trade secrecy and open biotechnology that *"knowledge producers have been somewhat reluctant to make use of collaborative licensing models in the life sciences in order to engage in hybrid licensing agreements involving the exchange of both patents and trade secrets*.". In particular, she discusses how the legislation in USA versus EU's (that is now more harmonised) has made a better climate for building trust and thus licensing of secrets as part of collaborations with unknown parties.

Trade secret management is not discussed explicitly in the open innovation literature, though trade secrets are. The framework of Profiting from Innovation. Teece (2018a, 44) connects trade secrets and intellectual property to the strategic management decisions on business models and dynamic capabilities. Thus, from Teece, management of trade secrets is needed for a strategic decision to engage in open innovation.

3.8 Modern Times: Digitalisation, platforms and ecosystems

Teece (2018b, 1367,1382) reviews the Profiting from Innovation framework discussed above and applies it to the digital economy. He concludes that intellectual property now is more significant than in the industrial economy and that licensing of trade secrets for many technologies is the "*default value-capture mechanism*", that is innovation appropriation mechanism.

The two-by-two matrix in (Knut J Egelie et al. 2019), that is Paper 1, presents a simplified, dichotomous view of openness and access. Openness comes in more variations than restricted and unrestricted. For example, the unrestricted information may not be indexed and thus impossible to find. There is a temporal dimension: The restricted information may be restricted only for a short time, such as a patent application. In the same way, access can be nuanced. Concentrated could be in the form of a non-shared trade secret, that creates an instant worldwide control. If the control is by a non-shared patent, the control is never world-wide as there are always numerous territories where the patent was never applied for or where it cannot be enforced.

The term "orchestration" is an important modifier. By orchestrated access, I mean that the access rights are dispersed in a planned way to achieve a specific objective such as encouraging a business model through patent pools (Teece 2018a). A common way of doing so is in the process for standardisation. A standard will not work unless all interested parties have access. Thus, essential patents are often administrated in a patent pool, where all are given access on "Fair, Reasonable and Non-Discriminatory terms, so-called FRAND-terms. FRAND from the meaning of the words sounds like chivalry re-invented. As discussed by (Heiden 2017), this is not the case: There is a battle to define FRAND. For example, to what extent can the holder of a patent of a small part in a mobile phone, use the threat of injunctive relief in price negotiations? However, a patent pool is an exception from the typical requirements of competition law. The actors can keep and coordinate a patent monopoly, but in a way that allows access for all through FRAND-like mechanisms. This mechanism is a response to the possibility governments have for breaking up monopolies, for example, through requirements of compulsory licencing. Another form of orchestration is the "patent pledge" scheme run by Tesla and Toyota. Here they offer access to the technology of large patent portfolios as a part of building an ecosystem around their technologies (Contreras 2015).

The relevance to trade secret management is that patenting in a field where there are standards, or where one seeks to build standards, introduce bargaining with the competitors and partners that are interested in the standard. Such positioning and negotiations begin while the patent applications are trade secrets. Also, the standard may be an industry standard or an ecosystem, that depends on trade secrets, as was the case with EU's antitrust case against Microsoft's Windows operating system (Podszun 2019).

In a patent pool, or for a standard, research results and knowledge are included in an unrestricted way. There is openness around the technology that is included. There can of course within the framework of a standard be restricted implementations that include trade secrets. However, this does not affect the openness of the standard. In an ecosystem, there will, in addition to informal governance mechanisms, be restricted knowledge in the form of trade secrets, as well as contractual relationships and other intellectual property. It is then possible to use strategic combinations of appropriation mechanisms, to differentiate between the various technologies and actors in the ecosystem. This differentiation creates a balance between competition and collaboration within the ecosystem (Jacobides, Cennamo, and Gawer 2018; Holgersson, Granstrand, and Bogers 2018).

3.9 *Terms are unclear*

In section 1.1.4, I discussed the concepts of secrecy, trade secrets and appropriation. Apparent from the initial overview, the innovation studies literature has not built an appropriation ontology. That is, the innovation researchers adopted the concept of appropriability from economists, such as Arrow (1962) and detailed it as necessary for each study. There are legal norms from the various national and international legal definitions of intellectual property, but these definitions do not focus on their function as appropriation mechanisms, nor management. As examples, Hurmelinna-Laukkanen and Puumalainen (2007) connect appropriability mechanisms with the objectives of a firm, that are long- and short-term value creations and barrier-building to competitors. Teece (2018a, 47) calls this "value creation strategy" with "appropriability" in parentheses.

There are also attempts such as the normative reference for statistics in the EU (European Commission 2012) that governs what data is collected for EU/EEA member states by Eurostat. This norm guides what data is collected in the Community Innovation Studies (CIS), and thus what appropriation mechanisms that are counted or not. The complete set of research literature that builds on the bi-annual CIS surveys is thus based on the definitions of appropriation in the Oslo Manual (OECD 2005; OECD/Eurostat 2018).[13] The scope of the Oslo Manual is to be a guideline and framework for innovation research at the level of the firm, covering product, process, organisational and marketing innovation. The mechanisms that are described there

[13] There is also a European standard recommendation CEN/TS 16555 on Innovation Management that includes a part on Intellectual Property Management (CEN 2015). The standard has very few definitions. The standardisation process is discussed in (Clausen and Elvestad 2015). Their point is that the standard is an important step, but the process has not come far.

should be a best practice synthesis. The Oslo Manual draws on more than 50 years of research. However, as Paper 2 discuss, the ambiguous definitions or lack thereof could make research results ambiguous.

3.10 Combining the perspectives and fields

3.10.1 Lines of interdisciplinary research

All papers in this thesis combine perspectives from the above literature, but also introduce literature relevant to the research question of the paper. Much of the literature I cite is interdisciplinary or belong to an interdisciplinary field, such as innovation studies. I end this presentation of the theoretical framework of the thesis with pointing to works or lines of research that combines views from management, economics, jurisprudence, sociology and psychology - and are essential to trade secret management:

> The Profiting from Innovation framework, as discussed previously in this chapter, combines the appropriability regime with the strategic decisions that a manager must take regarding trade secrets (Teece 2018b, 1986; Pisano 2006). The framework connects intellectual property management, including trade secret management, with the strategic decisions of the firm. This connection was what Granstrand (2000, 7) observed and reported in Japanese firms, and that spread, see section 3.3.
>
> The ethical issues will always be prominent in trade secret management. The philosopher and ethicist Sissela Bok's work discuss secrecy in all facets, including personal secrets, trade secrets and openness in science (Bok 1989, 1982). Her discussions draw on most fields of science and have an impact on all trade secret management issues.
>
> Trade secret management takes place in organisations. The understanding of secrecy as a normal and embedded part of the organisation has a bearing on all management of innovation and trade secrets (Costas and Grey 2014; Grey and

Costas 2016; Fan, Costas, and Grey 2017). The normality is what is recognised in the line of work that starts with the effect of procedures for trade secret management (David Hannah 2005), and ends (so far) with the concept of normative and bureaucratic secrecy appropriation mechanisms (David Hannah et al. 2019). These mechanisms form the procedures either normatively by the employees, or by rulemaking from management. This work includes the concept of creating a positive secrecy climate (Robertson, Hannah, and Lautsch 2015). Also, this line of work includes trade secrets in marketing, and thus the involvement of the customers (D. Hannah et al. 2014; David R. Hannah, McCarthy, and Kietzmann 2015).

Jurisprudence, the theory of law, is a field that produces valuable new insight for trade secret management in collaborations and open innovation. Rowe (2016) points to how trade secret misappropriation increasingly is based on cybercrime, but no longer only on a corporate level, but between nations. The rhetoric of war has become a part of the US national discourse on trade secrets. Firms must adapt, participate and be more responsible. The political side of trade secret management can thus be observed in the trade war rhetoric, as well as in the discussions on cyber warfare and national security. Petrusson (2016) presents models for how a university can interact with society to ensure that research results are utilised. The knowledge is modelled as intellectual assets, where intellectual property including secrecy are ways of governing the research results. Having transferable objects enables a connection to business models and alignment with the universities' objectives. The models clarify the challenges of managing trade secrets in academic environments. Finally, a recent legal study by Fromer (2019) discusses trade secrets and artificial intelligence in view of Roald Dahl's novel Charlie and the Chocolate Factory. The Oompa-Loompas are keepers of the chocolate trade secrets. They are sealed off from the outside and no-one can pass off as a tribe member. Her point is that the artificial intelligence machines and ecosystems,

> such as those of Amazon, Google and Microsoft, are the new Oompa-Loompas, the keepers of trade secrets. However, the secrets are kept too well: Trade secret law is also a law that creates commons of knowledge from reverse engineering and workforce mobility (Reichman 2011). With the new Oompa-Loompas, this societal benefit is lost. Thus, the fundament of trade secret law is gone, and Fromer's conclusion is: "*In sum, society might be well advised to remove trade secrecy protection for businesses operating in cloud computing, using data and machine learning, and deploying devices that automate human labor under certain conditions. We might want confidence that these businesses would instead choose patent protection—requiring disclosure—or "waste" resources on actual secrecy in a way that levels the competitive playing field*."
>
> Here, "actual secrecy" means successful use of a trade secret, in that it is not lost or developed in parallel. We are back where this chapter on theory began: Trade secrets do not depend on the law. Fromer suggests that in some technology areas, such as artificial intelligence, society should not encourage knowledge monopolies to form by supporting trade secrets legally, but rather encourage commons and thus remove the legal protection for trade secrets.[14]

3.10.2 Recurring topics and recurring gaps

As apparent from the many lines and areas of research that I have presented in this chapter, there is no theoretical framework that applies to trade secret management, but it is included or affected by many fields. However, there are essential, recurring topics and gaps at all levels:

> On the macro, system-level, there is the question as discussed above, to what extent society encourage trade secrecy by sanctioning knowledge flow or property rights. The new legislation in the EU/EEA and the USA may encourage

[14] Tramèr et al. (2016) show how they can reverse engineer – or "steal" as they call it -any machine learning model. This exemplifies Fromer's question – should such attacks be encouraged or punished by society? It is not obvious what benefits innovation and society.

knowledge flow in the form of licencing. The legal frameworks are compatible. Licensing between firms in different countries is facilitated because the parties know what misappropriation would be and that damages can be rewarded by a court of law. In trade with countries with a different legal tradition, such as China, Japan and Australia, the agreements need to be more detailed and the risk may be perceived by businesses to be higher. Policymakers can act within the legal framework or amend it. The literature concerning innovation systems and ecosystems discuss trade secrets to some extent, but rarely suggest amendments that concern management.

On the meso, firm-level the Profiting from Innovation framework points to how trade secret management is a part of strategic decision-making. Also, as secrecy is embedded in any organisational structure, the management of trade secrets must build on that, and not only on the legal regime. The discussion in the research literature on university-industry collaboration and secrecy concerns additionally the informal processes but fail to integrate the different views universities and industry have concerning the management of secrecy. The different views are consistently presented as a problem, such as industry trying to control the publishing of academic researchers, without suggesting integrative views or solutions.

On the micro, personal and team level, there is in the literature the understanding of secrecy and how it relates to human autonomy. The knowledge worker that change employer and the university researcher that works in a project with commercial ambitions meet challenges, as does any employee or manager that is required to keep a secret. The literature that builds on organisational psychology and management science both have agency as part of their theory, but with a different perspective. From economics, management science will emphasise the actions and instruments from contract theory. From psychology, agency implies intentionality and social cognitions. In trade secret management, these views meet at the micro-level, and the literature had not yet explored the different interpretations of agency related to secrecy.

4 Research design, methods and data

4.1 Research process and motivation

The thesis is the final part of an industrial PhD-project with NTNU, Faculty of Economics and Management, Department of Industrial Economics and Technology Management (IØT), financed by the intellectual property management consultancy Leogriff AS and sponsored by the Research Council of Norway with grant 247566. The primary motivation for this thesis comes from the understanding these parties shared: More research in trade secret management will result in useful knowledge and tools that can improve innovation management.

Historically, the management of trade secrets has not been studied much. There are few publications and a lack of theory. That is a problem, as it is a crucial part of fields of management science such as knowledge management, innovation management, and intellectual property management. Classical innovation studies, such as (Levin et al. 1987; Von Hippel 1982) point to how firms use trade secrets for creating competitive advantages, but few scientific studies follow on how to manage the secrets. In the area of intellectual property management, most research concerns patenting.[15] Thus, curiosity is a part of my motivation: I wondered why trade secrets were much less researched than patents when they were more important to businesses.

At the beginning of the last century, the famous American patent lawyer Fish (1907) published an article in Scientific American on trade secrets as a legal concept. His main

[15] There are no bibliometric studies. Combining (Wang, Chai, and Subramanian 2015) that counts the IP management literature, and (Bos, Broekhuizen, and de Faria 2015) that reviews the literature on trade secret management, around 10 per cent of this literature concerns trade secrets. Then patenting and trademarks would be the main parts of the 90 per cent.

point was that trade secrets are ethical and should be protected by the legal system. At the same time, there was also attention to the social function of secrecy. Simmel (1906), the leading German sociologist, discussed how secrecy is an inherent part of human nature and how secrecy can destroy integrity in trade. Both Fish' and Simmel's accounts of secrecy are from the age where technological innovations such as aircraft and telephone profoundly changed society and the rise of organisational psychology as a field of study. The societal changes from innovation are no less today. At the brink of war, and with tyranny rising in Europe, Bernal (1939) discussed secrecy and how it affects research. He was concerned about the utility of research and its place in society – including secrecy and how it affected the relationship between universities and industry. Now, openness in our democratic societies is constantly challenged. These historical trends make secrecy in collaborative innovation a fascinating topic. However, secrecy becomes even more interesting as a field of study when both the EU parliament and the US congress in 2016 introduced new legislation that creates better possibilities for using trade secrets in commerce and innovation. Then expertise in trade secret management can contribute even more to the competitive advantages of a firm.

Thus, working as an intellectual property management consultant, and teaching that topic at management courses and universities, I had a need to understand better the role of trade secrets and how to manage them. I found practical legal and anti-cybercrime literature, but little discussions on the management issues regarding interaction with other intellectual property. With nowhere to turn for learning, doing research was the best option. My research would then have to span both the large themes of secrecy versus openness and the governance of innovation processes to the practical issues of managing trade secrets as part of an organisation's portfolio of intellectual property and as a consultant and teacher, to facilitate learning.

My first encounter with the concept of trade secrets was in a late nineties small-talk discussion with what turned out to be a historian researching a raid in 1931 by the Paris police. He told me how the police officers looking for evidence of trade secret theft dramatically stormed the home of a previous Norsk Hydro research director. The director, also an engineer, was then a consultant to the international calcium nitrate industry. He was accused of stealing trade secrets in the form of technical drawings from Norsk Hydro. More engineers were involved, and the case ended in 1937 with most of them being acquitted by the supreme court. An illustrating quote from the court proceedings is the previous research director accused of stealing trade secret saying to his defence: "When we technologists meet, of course, we discuss technology" (K.G. Andersen, Yttri, and Wiedswang 1997). The indication is the same that is discussed by Von Hippel (1987): Presumably, secret information is freely discussed amongst engineers from different firms, sharing the best solutions to technological questions. There are openness and secrecy and a balanced revealing strategy. The engineers here acted as a closed circle, as an informal research consortium. However, they did so without the explicit consent of management, but with the implicitly agreed purpose of learning more than they give away. This balancing act of openness and secrecy, and how secrecy can create a commons for knowledge exchange are recurring themes in this thesis.

As I write this thesis, the Norwegian police have in December 2019 raided the homes of technologists in my neighbourhood. The American technology giant Cisco has accused former employees of stealing trade secrets as they joined an upstart developing competing equipment for videoconferencing. The case is in an early phase, and little is known. The case could concern topics of this thesis: How firms organise for managing trade secrets, how trade secret law creates a common of knowledge allowing reverse engineering, how trade secrets create lead time advantages and finally the sentiments of ownership to a secret opposed to how clusters work in technology diffusion, and how dominant design evolves.[16]

[16] Cisco became a leader in video conferencing by acquiring the Norwegian firm Tandberg. This created a cluster nick-named "Video valley "as new firms were founded by employees leaving. As Cisco continue to develop state-of-the-art products, these inspire competitors that may reverse engineer and develop products if they do not infringe Cisco's patents. Some of Cisco's patents are part of video-conferencing standards.

I was an assistant judge in a similar civil case where employees had left one firm and joined another. The question was if they had brought with them and used secret information on new products, and whether the new employer had taken steps to ensure that no trade secrets were transferred. Essential to the discussion in court was, to what extent the first firm had delimited the trade secrets, so that the employers could know the difference between their engineering competence and the firm's secret knowledge. This requirement for the owner of a trade secret to define it clearly is now in the current proposal[17] for the new Norwegian legislation implementing the EU directive on trade secrets (Norwegian Government 2019; European Commission 2016). During the court case, I noticed how both firms lacked procedures for managing their trade secrets, and how that affected the court proceedings. The evidence was not clear as the alleged trade secrets were not thoroughly defined during the research and development work. Other cases followed, where I was involved through my employer as an expert witness or as a consultant. With this background, I came up with several questions on how trade secrets should be managed, that became research questions in the papers of this thesis.

The last experience that motivated this thesis, was my role as a teacher of intellectual property management at various courses and universities. Every time I touched upon the role of trade secrets in innovation, I did not understand the topic thoroughly and I was not able to convey the core principles. On patents, copyright, designs and trademark, there is a rich literature and a precise vocabulary that applies to both law and management. For trade secrets, there is plentiful of legal literature. However, as I will come back to, the legal concepts are rule-based and do not connect well to the management literature. Also, the concepts are not developed in any detail and the normative guidelines for collecting, reporting and using data on innovation in the Oslo Manual are confusing (OECD/Eurostat 2018; OECD 2005). Thus, ontology and how to

[17] As of April 2020, the new law has passed all formalities in the Council of State, but is not in force yet.

teach trade secret management are themes that I explore. A final theme is that of teams and trade secrets, where I did not have the time to advance my research.

4.2 *Fields, research environments, levels and limitations of the study*

This thesis is interdisciplinary and by definition: The PhD-programme PHOL defines the study in industrial economics and technology management to be an education in the intersection of technology and economics, management and HMS.[18] The thesis is interdisciplinary with the papers mostly in the field of innovation studies and more broadly in management science. There are overlaps to industrial economics, jurisprudence, organisational psychology and sociology.

Innovation studies is an evolving field, that is in itself interdisciplinary (Martin 2012, 2016) . Martin (2012) discusses "Science Policy and Innovation Studies" (SPIS). He presents SPIS as an emerging discipline with limits towards other fields such as the more sociology oriented "Science and Technology Studies" and "Science Technology and Society", both abbreviated "STS". As an evolving field, the name and scope of the field itself develop and may include or exclude neighbouring areas. The terms "innovation studies" and "innovation research" are used interchangeably by Fagerberg, Martin, and Andersen (2013). In the same book, Lundvall (2013) suggests a definition of the theoretical foundation for innovation studies as: *"…the conceptualization of innovation as an interactive process involving many actors and extending over time. The focus of the analysis is upon individuals with heterogeneous skills or upon organizations with heterogeneous capabilities that interact with one another. They typically engage in information exchange, problem solving, and mutual learning as part of the process of innovation. In the course of this, they establish*

[18] In Norwegian: «Programmet er utformet for å utdanne kandidater for forskning, og for å forbedre private og offentlige beslutninger som involverer alle deler av virksomheten. Profilen til kandidatene som utdannes fra studieretningen vil være i skjæringspunktet mellom teknologi/naturvitenskap og økonomi, ledelse og HMS." fra STUDIEPLAN FOR PH.D.-PROGRAMMET I ØKONOMI OG LEDELSE 2018/2019, NTNU 2018-06-21..

'relationships' that may be interpreted as forming organizations, networks, clusters, or even 'innovation systems'."

That foundation applies well to this thesis. I have studied trade secrets in the context of collaboration and open innovation, that are processes with actors over time. The focus of the analysis in each paper differs, and covers both individuals (Paper 5), firms (Paper 4), collaborations (Paper 2) and the innovation system and policy issues, as in Paper 3.

As apparent by now, the literature I cite, both in this cover essay and in the papers, are thus from many fields of study. Earlier studies that concern trade secret management have all legal, market and organisational aspects and connects with the management of the intellectual property (Maurer and Zugelder 2000; Hemphill 2004; Al-Aali and Teece 2013; Bos, Broekhuizen, and de Faria 2015; Stead and Cross 2009). This interdisciplinarity reflects the topics of the research environments and conferences where I have contributed and that this thesis builds on, as shown in Table 5.

NAME	FIELDS	COMMENTS
The Strategy and Business Development Research Group, at the Department of Industrial Economics and Technology Management, NTNU	Innovation studies, strategy and business development, entrepreneurship	My home group at NTNU, with supervisor Roger Sørheim. See https://www.ntnu.edu/iot/stratforr I have attended research seminars and events, contributed to teaching and enjoyed the discussions and support from the group. This is also the link to NORSI, see below.
CIP – Center for Intellectual Property hosted by Gothenburg University, the School of Business, Economics and Law, the Department of Law	Intellectual property management, business law and economics	My other home group, with co-supervisor Ulf Petrusson, see http://cipnet.se/. I have attended research seminars and events, followed the steering group's work and enjoyed the discussions and their support, as well as their extensive industrial and academic network.

NORSI - Norwegian Research School in Innovation	Innovation studies	NORSI with 11 academic partners and 135 PhD students managed the innovation courses I attended and the NORSI conference. All the papers in this thesis have at some stage been presented to or commented by members of the NORSI faculty and my fellow students there., see http://norsi.no/about/
DRUID (annual conference)	Innovation studies	I presented papers at DRUID18 and DRUID19, an international conference with around 200 peer-reviewed papers. From https://conference.druid.dk/Druid/index.xhtml they highlight the interdisciplinarity: *"In particular, DRUID invites papers with new, mixed, or multi-disciplinary theoretical approaches or innovative methods that will benefit from the open-ended discussions at DRUID."*
EPIP - European Policy for Intellectual Property (annual conference)	Intellectual property policy questions from Economics, law, management science	I presented papers at EPIP2018 and 2019, see https://www.epip.eu/epip-conferences. The conference is aimed at *"scholars and practitioners interested in the economic, legal, political and managerial aspects of intellectual property rights"*
CIP forum (bi-annual conference)	Intellectual property management	I have managed two workshops on trade secret management at CIP-forum in 2016 and 2018. This forum has been an excellent platform for presenting my ideas and discussing with industry, policymakers and academics, see http://cipforum.org/
Academy of Management	Management science	I have enjoyed my membership, the publications and being a reviewer. Two of the papers in the thesis have been refused but received valuable comments. Paper 3 is accepted for the Annual meeting in 2020.

Table 5 Research environments and conferences that demonstrate the interdisciplinarity of the thesis

A further proof that the research in this thesis is of cross-disciplinary interest is that a Norwegian-language article that builds on the same material as Papers 1, 2 and 3 is accepted for publication in an article-collection on the intersection of intellectual property and contract law. The book will be published by Universitetsforlaget in

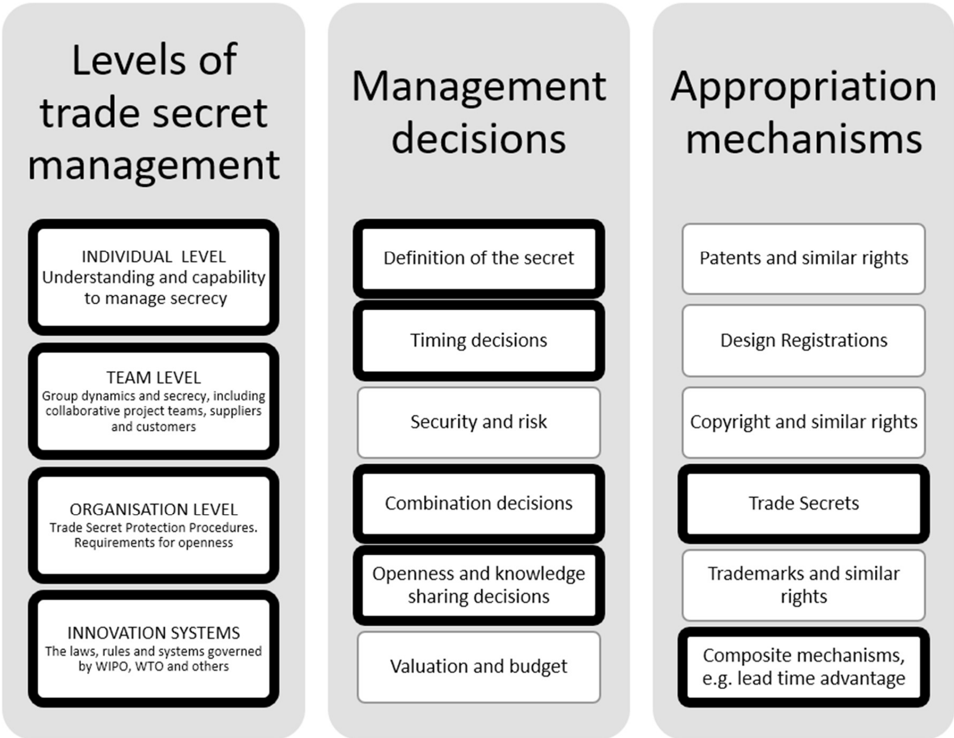

Figure 8 Trade secret management decisions. Circled topics are discussed in this thesis.

2020.[19]

Interdisciplinarity is also inherent in the types of decisions that managers of intellectual property face and the level to consider when making those decisions. Figure 8 synthesises management decisions from the literature. In the figure, study

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[19] Lie, HT; Egelie KJ: "Balansen mellom publisering og hemmelighold - tilgang til forskningsresultater i samarbeidsprosjekt mellom akademia og industri " in Irgens-Jensen Harald; Vislie, Camilla (editors), Kontrakts- og erstatningsrett møter immaterialretten: En artikkelsamling, Universitetsforlaget 2020. ISBN: 9788215030081.

levels are listed to the left and various appropriation mechanisms to the right. Trade secrets are here marked together with composite mechanisms, notably lead time advantage as the mechanisms I mainly discuss in this thesis. When using these mechanisms for the appropriation of innovation, there are crucial management decisions to be taken. The ones further discussed in this thesis are the definition of the secret (what are the attributes and limits versus general knowledge), timing decisions (how long will the secret last, and when should it be published, combination decisions (is the secret used as part of patenting or design registration, is it proprietary software under copyright, is it related to branding or other composite mechanisms). For lack of time and resources, I do not consider security and risk (such as cybersecurity) or valuation and the budget, that is crucial when a secret is shared as an in-kind contribution to a collaborative project or in licensing. Valuation of intellectual property is a broad and difficult field, where there are no recent studies on trade secret valuation (Lagrost et al. 2010; Peterson 2012), but a number of practice notes and

An illustrative industry case – Norsk Hydro’s new aluminium processing plant

E24!

-0,30% OSLO | 0,46% OLJE | 0,13% S&P | 0,09% EURO | -0,01% DOLLAR | 0,75% BITCOIN

HAAKON THU... MENY

Hydro åpner milliardanlegg i august: Tør ikke patentere teknologien

Snart innvier Hydro milliardanlegget på Karmøy som skal kutte aluminiumsverkenes energibruk. Noe av teknologien er så hemmelig at selskapet ikke tør å patentere den.

Media coverage from 2018 of Norsk Hydro's new plant for aluminium processing. The image shows the prime minister discussing with the CEO. A process innovation is appropriated by trade secrets. The headlines explain that the technology is so secret that they do not dare to patent it, and that the top-secret pilot plant runs according to the plans. The current investments are 430 million euro and will reduce energy consumption with 15 per cent.

https://www.hydro.com/en/media/on-the-agenda/karmoy/

Figure 9 An Illustrative industry case

blogs are available online. Leaving out both these topics is a limitation of this study. The same is leaving out the individual capability to manage secrecy. Any management decision on secrecy will affect individuals.[20] At the micro-level, I have mostly left out the individual but included in Paper 5 how to learn and understand trade secret management. For further studies of the individual capability for keeping trade secrets, starting points are Kelly (2002) that discuss the psychology of secrets in general and Delerue and Hamid (2015) who discuss personality traits and ethical judgements about trade secret misappropriation.

[20] Machine learning change that, and secrets could be kept by artificial intelligences. During my PhD studies I had the pleasure of co-supervising associate professor Lasse Øverlier, an information security researcher, who wrote an additional master thesis on machine learning. The topic of trade secrets and machine learning calls for more research (Øverlier 2017).

At the meso-level, I discuss firms and universities, and at the system-level, I do discuss how a change of the contractual framework for publicly sponsored collaborative research can contribute to more sustainable innovation. Notably, trade secrets are included in trade agreements both from the World Trade Organisation (WTO) and in the system administrated by the United Nations through the World Intellectual Property Organization (WIPO). Trade secrets are an inherent part of the international patent system that they manage, and also in the Paris conventions rules on unfair competition that 196 countries contract to (WIPO 2008). Aside from the apparent role of governments in legislation, courts of law, law enforcement, trade agreements and international conventions, all governments do have intellectual property offices (IPO) that grant patents and register trademarks and designs. Some offices, like the French, offer trade secrecy related service. As the IPOs that handle patent applications have routines also for handling trade secrets, this could be a starting point for researching possible new services.

4.3 Philosophy of science: Pragmatism

Pragmatism is an interpretive approach to the philosophy of social sciences. In contrast to realism, rationality is not so much stressed, but rather the usefulness of a theory or concept (Benton and Craib 2010). The philosophical foundation of this thesis matter, as the management of trade secrets and intellectual property concern immaterial rights. These rights vests on different principles. For example, patents are built on constitutive rules; without the national laws, there are no patents. The laws on trade secrets, however, are regulative, creating rules for something human by nature. In, for example, a critical realist view, there needs to be an independent reality of the objects of a study. Trade secrets do not fit well with having an independent reality; that is, they have a legal definition as patents have, but they do not come into being as an independent object. Having the background from Simmel and Bok, on the individual and social connotations of secrecy, presented in section 1.1.4, the realist approach to research on trade secrets become troublesome. Thus, pragmatism is the central philosophical influence on this thesis.

Pragmatism is a form of naturalism, developed late in the 19^{th} century. The early pragmatists, such as Peirce, James and Dewey included social practices and held that for a philosophy of science a concept – or a complete theory – should be evaluated on how effective it relates to or predicts phenomena. This view opposes that of realists who would seek an accurate description of reality. Pragmatism holds an instrumental view of concepts and theories: Scientific progress is nothing but improvements in explanations and predictions and does not require mirroring of reality or truth. It is a broad and pragmatic philosophy of science, with many recent contributions (Legg and Hookway 2017)

It is outside the scope of this paper to elaborate further on pragmatism. However, the pragmatist philosophy of science had a profound influence on this thesis. In Paper 2, it contributed to a change in the view of the concept "lead time advantage". In the early drafts of the paper and the conference presentations, I held the view that in principle, the concept was nonsense and did not exist. That perception aligns well with a realist philosophy of science. I experienced, however, that the concept was meaningful to many managers and had been used in the research literature, albeit with an ontological issue that is clarified in Paper 2. Thus, the usefulness of the concept became clear as I adopted a pragmatist view. The same holds for the other papers. They are all directed to usefulness in management practice, more than being effective mirrors of some management reality.

4.4 The overall research design

4.4.1 An industrial PhD-project

The overall research question "*How are trade secrets managed in collaborations and open innovation?"* is a broad question that does not direct the choice of research design. The main direction for the design was from the research project being an industrial PhD project. Thus, the design was guided by the need of the industrial partner, Leogriff. Leogriff is a small intellectual property management consultancy desiring to develop new methods and tools. The research design was further guided by the synthesised model in Figure 8 Trade secret management decisions. The decisions that a manager takes when using trade secrets for the appropriation of innovation, affects different levels – individuals, teams, organisations and systems. Thus, the design should cater to all levels. Further, the interdisciplinarity of the PhD programme, as discussed in section 4.2 influenced the design. Finally, from the needs of management consultancy, both theorising and models, as well as understanding how to improve learning, are research results that can be utilised.

The Frascati Manual (OECD 2015b, 50)[21] defines three types of research and development: basic research applied research and experimental development. The research questions are directed to the first two of the research types.

Using empirical methods follows the tradition of innovation studies as a field of research where a large part of the literature is empirically founded (Fagerberg, Martin, and Andersen 2013, 4,5,11). All the papers have ontological contributions, see section 4.5. There is to my understanding no standard methodology for ontological research as part of the philosophy of science. However, for ontologies in information science, there is. For papers 1,2 and 3, we built on a methodology discussed, following a three-step method. The research project was broken down into three sub-projects, addressing university-industry collaboration (Papers 1, 2 and 3), SMEs (Paper 4) and teaching (Paper 5).

Table 6 presents the papers resulting from the three sub-projects, with the main research type, as discussed above, the methodology, reasoning type and methods, as discussed below for each sub-project. Papers 2 and 5 are different in that they have a subjectivist interpretation rather than an objectivist one. This reflects that pragmatism

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[21] The Frascati manual by OECD is normative for *"The Measurement of scientific, Technological and innovation Activities".* To some extent, for example in Paper 4, this thesis does measure innovation activities. However, I use this typology to demonstrate that the objectives lead to different research types.

as a philosophy of science includes both interpretations, and both are present in the thesis papers.

No.	Short title	Main research type	Methodology	Reasoning type	Methods
1	Access and openness in biotechnology research	Basic research	Objectivist interpretation	Inductive	Archived contract study, mixed methods (quantitative, qualitative)
2	A new advantage	Applied research	Subjectivist interpretation	Abductive	Building on 1 and 3 – additional qualitative analysis
3	Monopoly spotting	Basic research	Objectivist interpretation	Inductive	Archived contract study, mixed methods (quantitative, qualitative)
4	SMEs	Basic research	Objectivist interpretation	Deductive	Survey Quantitative
5	Teaching	Applied research	Subjectivist interpretation	Abductive	Decoding of disciplines with multiple case studies

Table 6 Research types, methodology, reasoning and methods per paper

The courses I took during my studies have been important to the research design. Table 7 lists the courses with the papers and topics they mainly influenced. SFEL8000 is the basis for the work on ontology in all papers, and in Paper 5 for the epistemological discussion. The method course IØ8204 is the basis for the research and considerations on teams and trust, that contributed to Papers 2,4 and 5. Also, the course connects well with the qualitative methods I used in Paper 2 and the analysis in Paper 4. IØ8902 is a broad course on innovation studies and affects all the papers and the framing of this thesis within innovation studies. TIK9024 concerns research impact and thus the role of universities and research institutions and the impact on society. This is the background for Papers 1,2 and 3. The two last courses are NORSI courses and my co-author Knut Jørgen Egelie attended as well. Thus, much of the idea development for these papers took place during the courses.

Course code	Course title	Influenced
SFEL8000	Philosophy of Science for the Social Sciences	Paper 5 and ontology studies in other papers
IØ8204	Methods for Research and Consulting of Teams Emphasizing SPGR	Papers 2,4 and 5
IØ8902 (NORSI course)	Innovation Research - From Origin to Current Frontier	All papers
TIK9024 (NORSI course)	Research, Innovation and Impact	Papers 1,2 and 3

Table 7 List of courses and influence on papers and work

4.4.2 Abandoned research and research on teams

The research became better focussed during the PhD-project. Initially, I had ideas and questions closer to informatics and cybersecurity. Some of these questions related to the distributed ledger technology and smart contracts, such as Ethereum, and the possibilities for creating tools (Buterin 2013). As this platform became more speculative, and my dedication grew to the contractual study that resulted in Papers 1, 2 and 3, I had to leave this topic. I also abandoned further work on an ontology directed towards the semantic web and business modelling (Cevenini et al. 2008; Osterwalder 2004). As I gradually realised that fundamental questions, such as how to define and model lead time advantages, was not clear, I prioritised those questions. ‘

From constraints in time and resources, I had to abandon the initial plans of an experiment and a paper concerning teams. The research I did, influenced however Paper 2 and was useful in the work with Paper 4. Thus, I outline it briefly:

The research question was “*How are group dynamic models and tools of interest to trade secret management in teams?”.* The research method was conceptual and included studying and comparing three sets of literature:

- Empirical studies on trade secret procedures, secrecy climate, rule-bending studies, HR and innovation networks:
  (David Hannah 2005; D.R Hannah 2007; D. R Hannah and Robertson 2015; Robertson, Hannah, and Lautsch 2015; David Hannah et al. 2019; Jarvenpaa and Majchrzak 2016; Henttonen, Hurmelinna-Laukkanen, and Ritala 2016)
- Research on small groups, cross-boundary teams, trust and horizontal psychological contracts:
  (Alcover et al. 2017; Edmondson and Harvey 2018; T. Sverdrup 2012; Therese E. Sverdrup 2014; Therese E. Sverdrup and Schei 2015; Olaisen and Revang 2017; Sankowska and Söderlund 2015; Bouty 2000)
- The spin theory, personality theory, group dynamics tools and the SPGR framework:
  (Sjøvold 2007; Espevik, Johnsen, and Eid 2011; Kozlowski and Bell 2013; Delerue and Hamid 2015; J.S. Schultz, Sjøvold, and Andre 2017; Stålsett 2017)

I presented the preliminary results at the conference "Hvordan styrke person-gruppe relasjonen» (How to strengthen the person-group relation), arranged by The Norwegian Defence University College, The SPGR Institute and NTNU in Oslo 2019-05-14. The presentation was in the session on trust in teams, called "High value innovations, psychological contracts and the risks of trade secret disclosure – SPGR based tools in trade secret management". The resulting impact on Paper 2 was in the understanding of the mediating role of trust and psychological contracts.

4.4.3 Research design and trade secrets

Finally, during the PhD-project, I have been a consultant to several innovation projects that include trade secrets. I have taken notes and observed how these projects manage the trade secrets issues, the balance between openness and secrecy and the burden on managers and employees. The material from these projects has inspired the research but cannot be included in the thesis for reasons of confidentiality. The objective of the framework of the industrial PhD scheme is to allow such an exchange between industry and academia – even if the knowledge is in the form of insights, that remain tacit or secret.[22] Thus, this limitation was expected and planned in the research design.

4.5 *Ontology - from philosophy to informatics*

The term ontology has two connotations. The first is that of the philosophy of science. Here ontology defines what exists and an ontology for a field, like trade secret management, deals with what exists in that domain. It is a broader term than taxonomy, which means mere classification. The practical application of ontology in information science is the second connotation. Here ontologies are documented as formal statements often in computer languages, with diagrams that show how the terms of the ontology are associated (Smith 2004). A well-known example from management science is the ontology of the Business Model Canvas (Osterwalder 2004).

Ontologies are pervasive in many disciplines, where they are used to standardise terminology, enable access to domain knowledge, verify data consistency and to facilitate integrative analyses over heterogeneous research data.[23] Courvisanos (2007) defines an ontology of innovation. The objective is to develop a model of innovation decision-making and action. This ontology is a social ontology that connects with the view that human agency matters, and thus corresponds well with cooperative naturalism as epistemology, and with ontologies for law and sociology. As an ontology for this thesis, it is a basis for Figure 8 and the needed decisions listed there, and it connects with the need for decisions in Figure 3. Also, it makes the scoring model in Papers 1, 2 and 3 more natural to understand as there within agreements are decisions and actions that need definition. For future research, it is then possible to amend the

[22] https://www.forskningsradet.no/en/apply-for-funding/funding-from-the-research-council/industrial-ph.d.-scheme--doctoral-projects-in-industry/

[23] This is a realist, and not a pragmatist view of ontology. The importance is the inclusion of human agency. The difference would be that the realist view assumes that all concepts independently exist, whereas in pragmatism they can be negotiated and are only of interest if they are of use. For ontology in this thesis, the viewpoint does matter, see for example how we dismiss “secret education” in universities as a useful concept in papers 1, 2 and 3, see section 4.8.2.

model, as it can be affected by a new understanding of human agency. An example of such a new understanding is the secrecy appropriation mechanism concept in (David Hannah et al. 2019). This concept points to how rules for trade secrets will be both rules from management, and norms formed by employees. That is an ontological distinction that brings in human agency, and that would have been useful in the research design for this thesis, but that was published too late.

Ontology is not only a field of philosophy of science but a practical field in informatics with applications in management and law. Bullinger (2009) reviews practical ontology for innovation management and builds on the work on the semantic web. For intellectual property law, there have been attempts to establish legal ontologies, that could include trade secrets (Cevenini et al. 2008; Contissa and Laukyte 2008). The work on Papers 1, 2 and 3 aspires to be part of the foundation for an ontology for trade secret management. The application of such ontologies is in enabling machine learning (Casanovas et al. 2016).

Coming back to the research questions for the papers, from Figure 5, I have taken each question and rephrased it to an objective for how the thesis and the papers address ontology. The central ontological objective could be called a meta-objective. It sounds pretentious, but from a pragmatist point of view, an objective like “define and delimit what trade secret management is” would not be useful for a reality that changes and where the management of trade secrets is a process involving humans, organisations and social and political systems. Thus, the central objective is that of Identifying, investigating and clarifying ontological questions. Figure 10 shows this central ontological objective of this thesis, as well as the objectives for each paper, derived from the research questions in Figure 5.

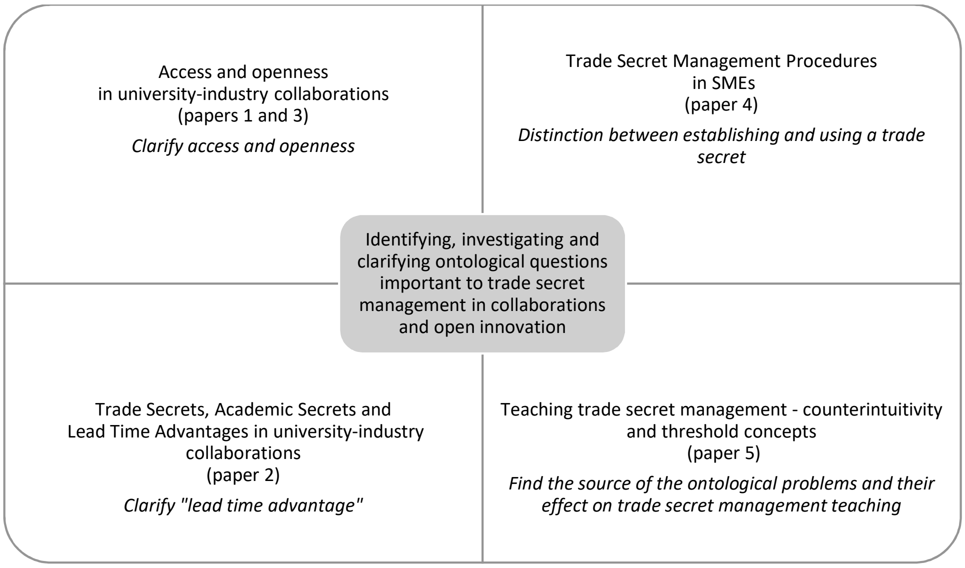

Figure 10 Ontological objectives for the thesis and papers

4.6 Epistemology: Cooperative and moderate naturalism

The epistemology of this thesis is that of cooperative naturalism, similar to moderate naturalism (Rysiew 2017). The concept of secrecy is founded on human perception, emotions, plans and actions (Bok 1989). Trade secrets cannot be studied quantitatively without combining it with qualitative results and insights from fields such as jurisprudence, psychology and sociology. Cooperative naturalism teaches that enumerations and quantitative results must combine with the result from social sciences, and thus fits with pragmatism as a philosophy of science. Evaluative questions cannot progress without qualitative results (Huaping and Xiaoming 2007).

Cooperative naturalism is from the etymology associated with collaborations and open innovation. It is also related to pragmatism as a philosophy of science. As pragmatism is a broad and evolving branch of philosophy of science, it is not possible to point out a specific epistemology of pragmatism (Benton and Craib 2010). Adopting cooperative naturalism as epistemology enables the view that secrecy is a process that involves both human emotions, legal concepts and useful concepts in innovation studies, management and economics.

In the same way, as for ontology in Figure 10, derived the central epistemological objective of this thesis, as well as the objectives for each paper, from the research questions in Figure 5. Figure 11 shows the central epistemological objective of this thesis, and the objectives of the papers in view of cooperative naturalism.

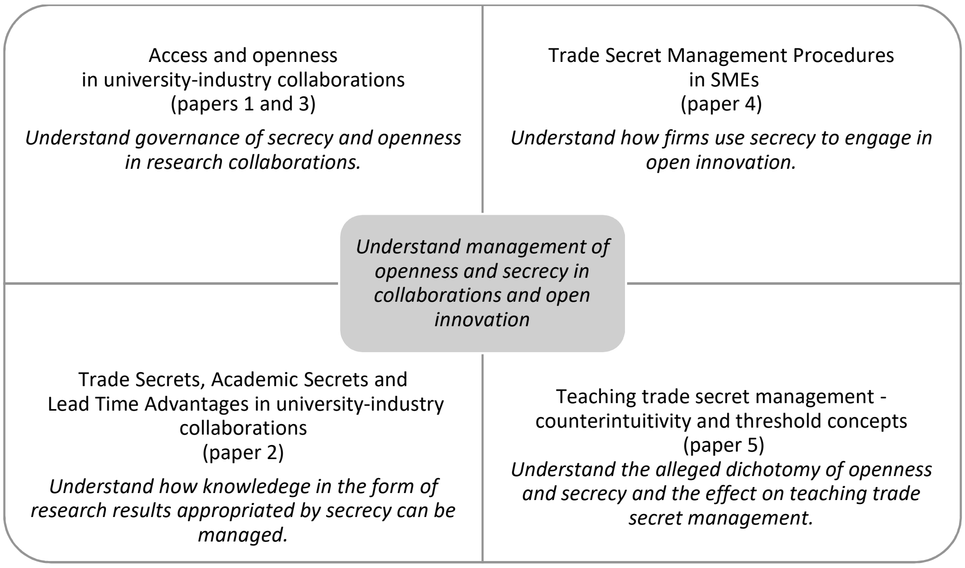

Figure 11 Epistemological objectives for the thesis given cooperative naturalism

4.7 *Ethics and gender issues in trade secret management research*

Rechberg and Syed (2013) discuss the fundamental issue of the conflict between the individual origin of knowledge and the organisation taking ownership and managing that knowledge. The effective transfer of the knowledge must be an ethical knowledge process that builds on a moral contract between the parties. When the ownership of a secret passes from an individual to an organisation, that conflict may be stronger than for other information that is not secret, because secrets are psychologically connected to a person’s identity and regarded as their private property (Bok 1989; Kelly 2002). Bok (1982) discusses this ethical challenge in science, and how scientists need to balance secrecy and openness. Thus, any research on the individuals and organisations that manage trade secrets, will have to relate to the question of ownership to the secret information.

The research design and data collection in this thesis avoid several ethical issues that concern qualitative research with interviews regarding secret information. In the data collection for Papers 1, 2 and 3, I studied research contracts together with co-author Egelie. Other co-authors and supervisors did not have access to the contracts, only to our anonymised data and scoring. We have published a few anonymised excerpts from the contracts. We tested the anonymisation with colleagues that we asked to identify the material by searches in the RCN project database. In Paper 4, the survey did not ask for any information related to persons. In Paper 5, the research builds on multiple cases, but none of them includes identifiable persons.

Thus, the research design of this thesis builds on data that is acquired without interviews and without asking questions that touch upon specific trade secrets. However, as mentioned in section 0, I have followed projects in industry and discussed with individuals on the management of specific trade secrets. David Hannah (2005) describes in detail the procedure he used for interviews, that included no recorded material and a signed non-disclosure agreement between the researcher and the interviewer, with the employer as part of the contract. This ensures both a legal framework and builds trust. I have used those guidelines. Räsänen (2018), in a study on the military intelligence community (that is not on trade secrets but state secrets), points to the ethical issues being complex and with personal and institutional perspectives as well as academic. The issues comprise trust, anonymity, policies and rules, laws and the reproducibility of research results, that I have considered during this research project.

There are questions about gender equality in intellectual property management.[24] For trade secret management there are few empirical studies. The two I have noted, do not find any difference between the sexes concerning trade secrets. Louis et al. (2001, 240) investigate secrecy in life science faculties, with gender as one of the variables. They do not find any statistically significant associations. Delerue and Hamid (2015) discuss gender and trade secret misappropriation on an individual level. They point to the literature being inconclusive on gender issues and unethical behaviour. In their study of personality traits that may affect how employees that change employer keep trade secrets, they do not find gender to be statistically significant.

4.8 *Papers 1,2 and 3 - Research design, methods and data*

4.8.1 The research design for Papers 1,2 and 3

This sub-project was formed in discussions with my co-author Egelie, consulting our joint supervisors Sørheim and Petrusson, and Egelie's supervisor Berit Johansen. Our idea was to use contracts to explore the themes of openness and access for the research results from collaborative projects comprising universities and industry. The project would fit well with Egelie's PhD-project (Knut Jørgen Egelie 2019) on access to biotechnology research results, and to my project on trade secrets, where openness is a fundamental concept. The inspiration was how the universities governed the development and commercialisation of the CRISPR-research platform, as explained in Paper 1. Egelie and I began the work on a possible research design the spring and summer 2016, and decided using mixed methods and that the research would be inductive. We studied the methodology of Gioia, Corley, and Hamilton (2013) and was inspired by that. The resulting, initial design is in Figure 12. The Baseline is the policy of the RCN combined with their contractual framework. Below is our study object – the consortium agreements together with the stereotyped motivation of the involved parties. Industry wants ownership and confidentiality, whereas universities want the

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[24] See https://www.wipo.int/women-and-ip/en/ and https://www.managingip.com/Article/3894941/Anna-Holmberg-we-need-to-increase-equality-and-diversity-in-IP.html

right to publish and access to the results for further research and education. The institutes want Freedom to Operate (FtO)[25] and payment for their work. Thus, the contracts are negotiated and agreed. Our initial hypotheses were that there could be an association between the openness and the degree of public funding, that there would be differences in confidentiality between industrial sectors and that the contract templates and framing could have an influence on the access to the research results. With the assistance from our supervisors, we applied to the Research Council of Norway (RCN) and the Ministry of Education and Research for access to the collaboration agreements we knew the RCN archived, that we got. We then considered the total amount of projects over the last ten years (around 20 000) ad decided that a survey of 1000 projects would be possible during our PhD-projects. To prepare for the data collection and analysis, we needed to develop an ontology for the contracts, as contract terms and wording vary. Also, as our field of study is innovation studies and not jurisprudence, we could not use legal ontologies. We realised that we would use mixed methods, both qualitative in the scoring, and quantitative from the other data on the projects. We followed David R Hannah and Lautsch (2011) on their recommendations for assigning numbers to data that are qualitative. Further, we were inspired by the approach of triangulation, where Jick (1979) discusses the combination of methods, that were of particular use in Paper 2.

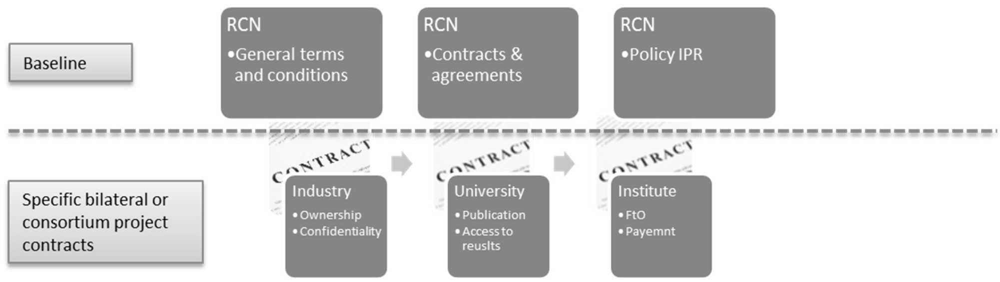

Figure 12 An initial research design for papers 1, 2 and 3

[25] Freedom to Operate (FtO) is to be ensured that no third party has intellectual property rights that can hinder the operations of the organisation.

4.8.2 Data and methods for Papers 1,2 and 3

We selected projects across multiple RCN research programs that span over the last decade. There were practical difficulties in finding and accessing the agreements due to archival issues. As a result, we removed projects we initially had selected because the agreements were in poor quality or not available from the archive. Also, we discarded a small number of selected projects, as they were not real research collaborations, but other grants. We had then around 500 projects that we scored and used as our data set, the details are in each paper.

Agreements based on contract templates constitute a large body of our data set. Such templates are often initiated by the RCN or the academic institution as well as the industry parties (to a lesser extent than the public institutions) but then subjected to negotiations between project managers and legal staff from the parties involved in the projects. We used templates and known contracts to start the work on an ontology for the contracts in view of our field of study:

- EU Horizon 2020, EU Framework 6 and 7, the DESCA model templates (DESCA 2017)
- The Lambert Toolkit, as discussed in (Eggington, Osborn, and Kaplan 2013)
- University collaboration agreements known to us, mainly from NTNU
- RCN agreement templates (The Research Council of Norway 2019)

We placed different terms from these contracts and templates on a whiteboard and explored connections. Eventually, we mapped them using Mindjet Mindmanager. We followed a three-step method for information science to create an ontology (Rosemann, Green, and Indulska 2004, 117). We used as far as possible the visual notation for OWL-ontologies, as shown in Figure 13 (Lohmann et al. 2016). We decided, due to the workload and the scope of our projects, not to create an ontology usable for the semantic web, but to prepare for such future research.

An example from the discussions we had, is that the definition for IPR (Intellectual Property Rights) is not a definition in legal terms and is not ontologically unambiguous.

First, we merged the terms IP and IPR. From a legal theory point of view, there is a distinction between the property and the rights to the property. There could be one invention, one property, covered by several IPRs, e.g. patent and copyright and design rights. Then we considered existing legal ontologies. The ALIS ontology, for example, shows that there are nine types of legal, moral rights, such as the "rights to reconsider right to or withdraw assignment to exploitation " (Cevenini et al. 2008, 173). Our decision was not to detail the evaluation at this level.

Another example is that one RCN template uses the term "academic rights" as something the university or researcher will keep (The Research Council of Norway 2019 "Simple Collaboration Agreement"). The term has no legal definition but is connected to the discussion on academic freedom (S. Wright 2016, 70). We decided to leave it out of the ontology. As the difference between IP and IPR makes no difference in the discussion on access, we decided to treat the terms as equivalents, and use IP. We then defined IP and IPR, in line with many contractual definitions as:

> "Intellectual Property" "IP" or "Intellectual Property Rights", "IPR" means all industrial and property and property rights including patents, utility models, rights in inventions, registered designs, rights in designs, trademarks, copyright and neighbouring rights, database rights, moral rights, trade secrets, and rights in confidential and proprietary information, all whether registered or unregistered and including any renewals and extensions thereof, and all rights or forms of protection having equivalent or similar effect to any of these which may subsist anywhere in the world and applications for registrations of any of the foregoing.

We would need these types of formal and normative descriptions in a complete ontology, but we did not need them in full for going forward with our research.

The circles in Figure 13 are concepts, which are classes in the ontology. The size does not reflect the number of members or individuals in the class; it is just an adaption to the text. The diamond is the only individual in this ontology, RCN. They are the only public funding agent. The rounded squares are concepts that are close to datatypes. They will have a clear value. Also, their relation to other concepts in the ontology is simple. The arrows show relationships. The dotted lines indicate that the relationship is not important in the scoring model. We have not thoroughly reviewed the direction of the arrows, and the use of “has”, “is” and “subclass”. We progressed with the relationships from Figure 13 to create a scoring table to be used. In Figure 13 we selected the shaded classes for possible future variables and for our data collection and scoring.

We received data for each project, such as the budget and start date and the number of participants from the RCN. We decided the classes to be scored based on how they connected to the research question, the class called “AccessRightsFromCollaborationAgreements”. Notably, we had not yet developed the distinction between openness and access, that is a research result from Paper 1. As an example of how we selected the classes to be included, “OwnershipOfBackground” was not selected for scoring. The reason was that this ownership is never contested. In all templates, we surveyed ownership vests with the party that brings the background knowledge into the project. Later, as we worked on Paper 2, we realised that this class has more connections to confidentiality and publishing rights, as a result from that paper is an association between background confidentiality and the possibility of trade secrets in the research results. Another example is how we dismissed the class of “secret education” in universities. From a realist point of view, this class exists, but from pragmatism, it can be dismissed as it contradicts all academic norms. Thus, Figure 13 is not a complete ontology for the sub-project but served as a tool for creating the scoring table.

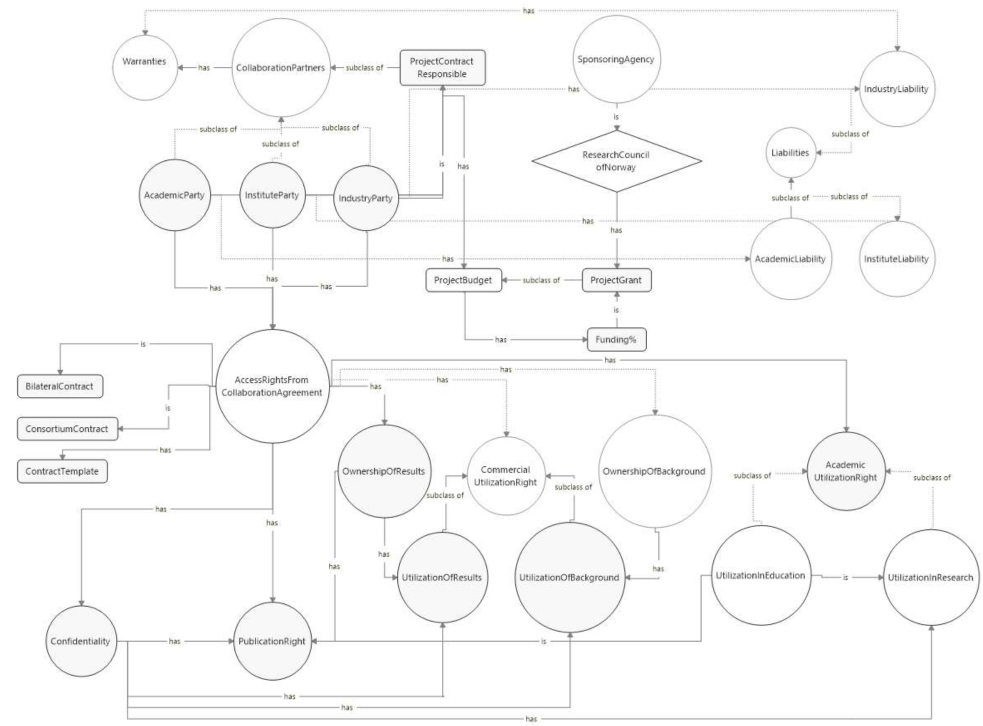

Figure 13 The initial ontology that we used for the scoring table

Egelie and I developed the scoring table based on contractual terms. We wanted the scoring to be objective and relate to the wording of the agreements. We selected the terms to be scored:

> **"Access rights"** is a term related to IP. The term means those rights (e.g., licenses or user rights) to use knowledge or Background IP given by the owners of the knowledge or pre-existing knowledge to others. Another term for this is the right to **"Utilization".** We used that term, as it better gives associations to rights for commercial and educational use, as well as for further research.
>
> **"Ownership"** is regulations about who owns the relevant Background IP and Foreground IP..

“Foreground IP” means IP or project results generated or developed during the lifetime of the project. The term used for EU-funded research is now **“Result”**.

“Background IP” means all Intellectual Property or knowledge in the formal possession of a project partner at the start of the research project

Regarding the term “Further research and education”, or **“Academic Utilization Right”**, universities need to secure a fair return for public investments in education and research. We did distinguish between utilisation in education and utilisation in research. However, we decided to score them combined. From the discussion on the ontology, we saw that confidential education was a theoretical possibility. A university may do future research that is kept confidential, at least for a given period. We then understood that we could use a combined concept for education and research, connected to an understanding of confidentiality and the right to publish.

“Publication” regulates the partners’ ability to publish information and results from a collaboration project. Academic researchers publish the results of their work to disseminate knowledge to the public. Universities rigorously want to protect the rights of its researchers to publish. On the other hand, companies may be concerned that publishing could reveal their confidential information or cause a loss of IP, such as patents or trade secrets, resulting from the research.

“Confidentiality” regulate what information is deemed to be confidential and what is not. Clauses on confidentiality will regulate the time frame the confidentiality obligations will be in force, and what clauses will survive the termination of the agreement.

“Liability” means that a party not owing or controlling the IP will be concerned that the party owning or controlling the IP are handling the ownership correctly. Warranties are often seen together with liability. It is common to highlight the novel nature of the research and to say that results cannot be guaranteed and the funder uses such results at its own risk. Liability is often tied into or limited to the amount of funding received by the institution, and indirect and consequential loss is excluded. We initially decided to regard only the **"academic liability"**, to what extent the universities accepted liability.

The term **"warranty"** has a variety of subtly different legal meanings, as a promise contained in a contract that certain facts are true. Eventually, we decided to leave both warranties and liabilities out of the model. We observed that they had a low effect on scoring.

In addition, we decided to note if an **RCN template** was used, and if we found explicit clauses on **trade secrets**, and if so, what was agreed. The last notes became the basis for Paper 2.

We graded each of the parameters in the scoring model 1 to 5 according to different descriptions of the ontology terms. A score of 5 for a descriptive parameter is for the highest degree of access for the university and the public. The university will own the results, and they will be publicly available. This does not preclude patents owned by the university. It may, however, preclude the universities from using trade secrets as an appropriation mechanism unless the industry partners agree.

A score of 3, indicates a balanced situation. All foreground IP is jointly owned. It will normally be published, but the university can agree to it being kept secret. There are no provisions on further use in education and research, as the university is a joint owner.[26]

A score of 1 indicates that the industry has ownership and can require that all results are kept confidential forever. The university partners are liable if a confidential result is published.

[26] Note that the laws on joint ownership of intellectual property are very different from country to country, see (Belderbos et al. 2014) for a discussion and references.

We created a first version of the scoring model and tested it on 30 projects that Egelie and I scored separately. We compared the scoring and did some minor adjustments from that. We then divided the work between us and consulted on the few cases of doubt. The resulting scoring model is in Table 8. We later adjusted some of the wording to be clearer and free from grammatical errors, to be used in Paper 1 (Knut J Egelie et al. 2019).

SCORE	1	2	3	4	5
Ownership	Industry owns all IPR and project results	A specific party owns Project Results if based on own background, dominating contribution or own commercial interests. Otherwise jointly owned.	All Project results are jointly owned. Separate agreements for Access rights	Ownership of all Project Results is individually owned. Where several Parties have carried out work generating Project Results and where share of the work cannot be ascertained, they have joint ownership,	Academic institution owns all Project results.
Foreground	Industry has exclusive user rights to all commercial use of IPR and project results.	All parties have by default exclusive (within specified field of use) or non-exclusive, world-wide, royalty free User Rights to any utilization of all the Project Results,	All parties granted non-exclusive user rights to all Project results to be able to utilize own Project result.	All parties have royalty free user rights, but only during the project period to results that are needed to perform utilization of own Project result, further user rights may be given upon request.	Only academic partner has specified user rights of Project results.
Background	All background results are free for all parties to use for any purposes. May be transferred if some Project results are depending on specific Background.	Background results remain the property of the Party introducing it. Such background should be accessible to other parties.	Background Results remains the sole property of the Party introducing such to the Project. May be accessible to other partners upon request.	Only background according to a predefined list may be subject to access rights for other project partners. Only when needed to utilize own Project result during the Project Period. Access to such Background for Commercial Purposes after the Project could be agreed.	No access to others Background results is granted for whatever purpose.
Further research and education	There are no utilization rights for an academic partner (or others) of access to further R&E of foreground results.	**Intermediate**	Not explicitly clarified if academic partners have utilization rights for further R&D.	**Intermediate**	All partners have user rights to further R&E
Publication	All dissemination of project results is strictly controlled.	Project results must be published but could be delayed	Results shall be published, but publication must be sent to	Publications could be delayed due to patent or other justified grounds,	No publication restriction. Specified that results must be published

SCORE	1	2	3	4	5
	No publications allowed.	according to participants needs. Not specified publication veto for academics.	Steering committee which could object and request modifications before publication.	but according to Norwegian laws. Must be clearly stated that results must be published within a time frame.	
Confidentiality	All Information is by default confidential if not already public. No specified time limits or other limitations.	All Project results and background information disclosed is by default confidential if not already public, limited in time.	Project Results and Background information is confidential if marked and justified for particular reasons and limited both in content and/or time.	Project partners have to specifically call for confidential information. Must be marked Confidential, time limited and approved by a Project Board. Parties could refuse.	No confidentiality conditions specified
Academic liability and warranty	All Parties, also academic, warrants that Background or/and Project results will not infringe third parties. Parties are liable for damages by breach of confidentiality and any use of their results or information.	**Not used**	Not specified any warranty. Partners are liable only for own actions, not specified if the academic partner is liability for other partners use of their results or information.	**Intermediate**	Specified that Academic institution is not liable for any use by others of results or information given by the Academic partner. Academic institution gives no warranty that any advice or information given will not constitute or result in any infringement of third party rights.

Table 8 The initial scoring model

We analysed the projects over one year. The scores were recorded in Excel spreadsheets. The agreements were extracted in batches by RCN employees from the RCN archives. The initial selection was random. We then selected some programs with projects extending over around ten years. We selected programs spanning different topics and technologies, such as energy, aquaculture, and nanotechnology. Around half of the projects selected initially, were not available, or could not be scored due to lack of contracts, erroneous files scanned or unreadable scans. Due to time constraints, we could not go to the archives and look them up manually. Due to confidentiality issues, we could not contact the project managers or parties to get their copy of the agreement. We compared the set of the inaccessible agreements with the ones we got in terms of the number of participants, budget, funding degree and types of projects. We found no major differences or systematic errors and concluded that our set is representative. We scored and recoded data from 483 projects with 3937 agreements.[27] Our final spreadsheet had 43234 data in 8694 fields.

For Paper 1, we selected the 162 biotechnology projects in our set with the debate on CRISPR as the starting point. For Paper 3 we used the complete set of projects. The work on the regression models for Papers 1 and 3 was mainly performed by co-author Grimpe, using the STATA software. Egelie and I did control work and tested out other models using the SPSS software. The conception of the two-by-two matrix took place over several months with discussions and drafts, based on the recoded scoring and the need to differentiate between openness and access. For Paper 2, we selected a subset of 52 projects that had scores or clauses that allowed trade secrets. For these 52 projects, we re-coded them, using the NVIVO 12 software for the qualitative study and for making the cross-tabulations. In addition, we did a preparatory ontological study, that I discuss next.

4.8.3 The ontological basis for Paper 2 and the definition of lead time advantages

In Paper 2, we discuss the concept of "lead time advantage ". I addition to what is presented in the paper, our method included an ontological study of lead time advantages and the related concept "complexity of design". To keep the focus on the most prominent mechanism, and for limitations on the length of the paper, we do not present the method used for the initial analysis.

We started by studying how the Oslo Manual suggests a selection of formal and informal appropriation mechanisms. They are to be included in surveys and studies such as those made by OECD and Eurostat. The process of selecting these mechanisms is unclear from the manual itself, as discussed in section 3.9.

When the manual is applied by Eurostat in the CIS 2012 Harmonised survey questionnaire[28] they use the suggested mechanisms when they ask "*How effective*

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[27] In Paper 3 we use N=484 projects, as we decided to split a project that from a contractual point of view was more like two projects.

[28] Available at http://ec.europa.eu/eurostat/cache/metadata/Annexes/inn_cis8_esms_an4.doc

were the following methods for maintaining or increasing the competitiveness of product and process innovations introduced during 2010 to 2012?"[29] The methods (i.e. appropriation mechanisms) can then be scored with low, medium or high "degree of effectiveness", or marked "not used".

This questionnaire merges the formal and informal secrecy categories into "Secrecy (include non-disclosure agreements)". The merger means that it is difficult to understand what is measured, as the effectiveness of an informal method could be very different than for a formal method. As examples:

> Formal secrecy: A trade secret that is well documented, e.g. in the form of formal technical documentation with controlled access, and non-disclosure agreements, can be sold or licensed. If the secrecy is lost due to misappropriation, it is possible to use the legal system for redress.
>
> Informal secrecy: (Costas and Grey 2014) define informal secrecy by *"examples such as confidential gossip which operate unofficially and are organised through social norms."* This definition is based on a view of secrecy as a social process. Based on the legal definitions[30] of trade secrets, a secret that is not a trade secret and not legally confidential, and thus informal, could be for example undocumented knowledge in a firm about a competitor's key personnel.

The empirical studies by Gallié and Legros (2012) and others, as well as American researchers of law such as Reichman (2011) and Lemley (2008), support the view that trade secrets are formal intellectual property. However, recent research such as Zobel,

[29] Eurostat refers to the results in the table headline as being for "importance" for maintaining or increasing the competitiveness in the enterprises, and not for "effectiveness" as is clear from the table itself and the questionnaire.

[30] They differ from country to country, but examples are in (European Commission 2016) and (Congress of the United States of America 2016).

Lokshin, and Hagedoorn (2016) and also B. Hall et al. (2014) and Huang et al. (2014) build their empirical studies on data where secrecy is categorised as informal.

A distinction can also be made between trade secrecy law and how trade secrets are property, as opposed to unfair competition. There is a connection to how trade secrets as an appropriation mechanism interact with lead time in the quote "*there is a property right in trade secrets in the form of entitlement to either lead time or compensation for lost lead time due to a wrongful appropriation*" (Reichman 2011, 187).[31] Lead time as appropriation mechanism is here seen as something connected to the ability to keep secret the development project itself or its technology. Unfair competition is a legal term that could include misappropriation of trade secrets, but is much more comprehensive, including, e.g. trade libel, passing off and fraud.

As discussed, firms use a multitude of appropriation mechanisms. These mechanisms are interconnected and can be hard to separate from one another; the mechanisms that are categorised as intellectual property are defined by laws. They are used in combination. A single technological innovation can, for example, be appropriated by one or more of copyright (software, artistic design, data), design registration (user interface, ornamental design), patent (new method or utility), trademark (brand), trade secret (details of inner working, customer preferences).

As preparation for Paper 2, we then needed to establish ontologically whether lead time advantages and complexity of design depend on the other mechanisms from the Oslo manual. We established the dependency by means of Table 9 and Table 10.

[31] Wrongful appropriation is as in "theft" and not as something that wrongfully protects a competitive advantage.

Formal method of the Oslo manual	Effect on "Lead time"
Patent	Patent applications that are public can defer others from using the technology, as protection can be retroactive from publication date. Filing a patent application will create a better understanding of competing technology and technology that can be licensed-in. Patents or other IP is needed for licencing out, speeding up technology transfer, or licensing in, to reduce development time.
Registration of design	Design registrations make it harder to copy successful ornamentation. Thus avoiding direct copying. Design registration or other IP is needed for licencing out, speeding up technology transfer, or licensing in, to reduce development time.
Trademarks	Launching a product under a known brand, with a registered trademark will speed up market acceptance. A trademark will make it easier for customers to associate with the product and refer others to it.
Copyrights	Copyright makes it illegal to copy parts of a product or service without permission. Copyright or other IP is needed for licencing out, speeding up technology transfer, or licensing in, to reduce development time. This includes the use of Open Source software or Creative Commons media that will speed up development time.
Confidentiality agreements and trade secrecy	Trade secrets or other IP is needed for licencing out, speeding up technology transfer, or licensing-in, to reduce development time.

Table 9 Intellectual property effects on lead time advantage

Formal method of the Oslo Manual	Effect on "Complexity of design"
Patent	Patents, in particular "patent thickets" (Cockburn, MacGarvie, and Müller 2010) can i) extend the appropriability to technology not in the innovation, thus keeping competing technology away. ii) confuse competitors as to how the product is made.
Registration of design	Small. (Some of the same effects as for patents, but easier to develop around).
Trademarks	Small. (Some of the same effects as for patents, but easier to develop around).
Copyrights	Small. (Some of the same effects as for patents, but easier to develop around).
Confidentiality agreements and trade secrecy	The complexity is only there if it is either: i) partly secret and not possible to reverse engineer – or if it is ii) extremely advanced so that there are no means available for copying. This is like "lead time advantage". If it cannot be copied, it has the ultimate lead time advantage. It is different from "time to market", as a substitute product or service could launch and take over the market position. The "Springboard Doctrine" is a legal principle where misappropriation, e.g. of a secret, technical detail, leads to the offender being barred from the market for a given time. The idea is to give the rightful owner of the secret added lead time (Pitchfork 2007).

Table 10 Intellectual property effects on complexity of design

The complexity of design is at its core the ability of not being reverse engineered and keeping tacit knowledge.[32] One could imagine a technology that is completely observable, but so complex that it cannot be copied by imitators. However, then – this is mainly a lead time advantage. In other words, when removing the secrecy from the complexity of design, one is left with the time it takes for a competitor to respond.

In summary, from the ontological study, the lead time is strongly correlated with other mechanisms and could be confused in surveys. The complexity of design shares the same characteristics. Informal secrecy is not an appropriation mechanism. The lack of clarity can be problematic for understanding innovation processes where many appropriation mechanisms are used. The appropriation mechanisms of the Oslo Manual are not orthogonal. They are mostly intellectual property or composed of intellectual property. To examine this question further, we revisited the literature and found that "*lead time remains a poorly understood strategy. It is difficult to know by reading and analysing surveys whether the positive assessment of lead time by respondents is a description of a fact (every innovator enjoys a lead-time situation) or is taken as an explicit (not default) strategy*" (Lopez 2009, 34-35 Comment by Dominique Foray). Further, the actual use of the mechanisms per innovation and firm is a complex mix. We found two studies that look at the correlation between the use of mechanisms: (Gallié and Legros 2012 Table B.7) and (Leiponen and Byma 2009 Table A2). These correlations indicate that lead time and complexity of design is used together, as is complexity and secrecy.

4.9 Paper 4- Research design, methods and data

4.9.1 The research design for Paper 4

How firms and organisations can use trade secrets may depend on their size and resources. There are notable differences between SMEs and larger entities (European

[32] Bruneel, Spithoven, and Clarysse (2017, 259) shows how such complexity for technology-based firms associates negatively with trust, that is the more complex the technology is the less they trust others in collaboration.

Commission 2013c, 149). To study the organisation level and how trade secrets can affect open innovation, SMEs are attractive. The literature points to how SMEs may have difficulties with patenting cost, and that trade secrets may be a better alternative if they are to engage in open innovation (Brunswicker and Vanhaverbeke 2015, 1244). Two of the authors of paper 4, Hansen and myself, had worked on a study and report commissioned by the Norwegian Industrial Property Office (NIPO, Patentstyret) and Innovation Norway (Hansen, Lie, and Vestergaard 2014). The study concerned the SMEs' knowledge about types of IP and their use in business, and the firms' need for public and private IP-related services. With a growing interest for trade secrets, we included several questions concerning the establishment, use and management of trade secrets. Due to time and resource limitations this data was not thoroughly analysed in 2014. The report merely lists some numbers for comparison with patents and other intellectual property.

The research design was then initially guided by the possibility of using this data set. NIPO and Innovation Norway generously allowed further research on their data in 2017. Oxford Research contributed resources and proprietary databases, including SME data. Given the available resources and time, we decided to use deductive reasoning on the existing dataset, answering the research questions on the SMEs establishment and use of trade secrets, their use in knowledge exchange such as licencing and associations to management procedures. We started exploring the data set and found that there were no good indicators of innovation in the survey data. We then decided to combine the data set with accounting and tax data for SMEs, and use capitalisation of research and development costs, as well as a tax deduction for research costs (Skattefunn) as proxies for innovation. From this new dataset, we could then make models for regression analysis.

We adjusted the research design in 2018 after comments from an anonymous reviewer from the Academy of Management. The reviewer pointed out that our distinction between establishing and using trade secrets was not found in the literature and could be of importance. We then decided to explore this distinction with the regression models.

4.9.2 Data and methods for Paper 4

We collected the survey data in late 2013.[33] We first built a Norwegian language questionnaire on SMEs use of intellectual property. The survey had around 60 questions on IP use and management. We excluded some questions if the respondent scored the topic as irrelevant. Depending on their score, the survey form guided the most IP intensive respondents to more detailed questions. Many of these questions were on the management of IP and trade secrets, as discussed in Paper 4.

We used Oxford Research's proprietary database of 145720 Norwegian SMEs. We excluded firms without commercial activities and e-mail address. We sent out 61781 questionnaires using e-mail with a link to a web form with the questionnaire and received 3871 complete responses. We found accounting and tax data from 3218 firms. All analyses were performed with the Stata programme in version 15.1.

4.10 Paper 5- Research design, methods and data

4.10.1 The research design for Paper 5

Threshold learning is a new theory in educational sciences (Tucker et al. 2014; J.H. Meyer and Land 2005). In discussions with co-author Hokstad we gradually, for three years from 2015, found that this theoretical perspective might be useful for learners of trade secret management to understand trade secrecy better as a managed process and see the continuum of openness and secrecy.

To advance further, we set the objectives of substantiating threshold concepts as a framework for teaching trade secret management, and to exemplify this with a curriculum outline. We decided to research based on teaching cases in the form of material and observations, using abduction as reasoning. However, we found that

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[33] The data collection may be regarded as part of the PhD-project in accordance with https://lovdata.no/forskrift/2018-12-05-1878/§11-4

teaching material is scarce. We discussed further with co-author O'Connell who has long experience in teaching the subject and develops management software. Based on our collective material, we documented cases of teaching students at master level and teaching managers in dedicated courses. We chose the method, as described next.

4.10.2 Data and methods for Paper 5

We used as a basis, teaching notes, presentations and teaching material from NTNU, Leogriff, CIP, Chawton Innovation Services and Imperial College as cases. We then applied the "Decoding across Disciplines" method (Miller-Young and Boman 2017; Middendorf and Pace 2004). This is a seven-step, iterative model based on observing bottlenecks in students' learning; finding what experts do, model the tasks, finding out how students will practice and what will motivate them, study the students' mastering and sharing the new knowledge. We early identified counterintuitive topics as bottlenecks for learning, and then followed the method in the discussions between the authors. However, due to lack of time and resources, we could not systematically perform the step of studying the students' mastering. By abduction, we have then created a testable hypothesis in the form of a curriculum.

5 Presentation of the papers

5.1 Paper 1

5.1.1 Summary

Title:

Access and openness in biotechnology research collaborations between universities and industry

Egelie KJ, Lie HT, Grimpe C, Sørheim R

Stated research objective in the paper:

"To identify the provisions around access and openness that attenuate or aggravate knowledge monopolies in collaborative biotechnology research projects."

Research design:

Analysis of the contractual terms in 162 publicly funded collaborative research projects in biotechnology – a subset of the projects in Paper 3.

Contributions:

i) An ontological differentiation between openness and access

ii) A tool useful for funding bodies, policymakers and research managers

Highlights:

Paper 1 studies the contracts of biotechnology collaborations between university and industry. Biotechnology is a field of industry where trade secrecy is controversial, because of the ethical questions. These questions are both on openness and secrecy, but also on private versus public ownership and use rights. Biotechnology research can spawn broadly useful technology research platforms such as CRISPR/Cas9, the technology for editing genes, which has frequently been criticised as a knowledge monopoly. Prior examples are the polymerase chain reaction and recombinant DNA.

The access to such technology can be restricted, and utilisation of research results depends on the contractual provisions devised by the owners of the technology. Thus, Paper 1 studies the conditions under which knowledge monopolies are likely to emerge. It identifies contractual provisions that govern the extent of access to and openness of research results; and it evaluates how the project participants in free negotiations agree on ownership and user rights from intellectual property, as well as on confidentiality and publication rights. The framework developed and presented as a two-by-two matrix, identifies four cases – knowledge monopoly, attenuated monopoly, closed circle, and open science. These are useful for unravelling the complicated contractual provisions and their interrelationships. Policymakers and funding bodies can assess the likelihood of emerging knowledge monopolies ex-ante. Then they can assess the norms of open science versus the utilisation of the research results and consider the level of public funding.

5.1.2 The research question of the paper related to the thesis' question

In Figure 5 I break the research question of the thesis on the management of trade secrets in collaborations into the overall question for the papers. For Papers 1 and 3, it is "How is the societal utility of collaborative research results affected by the governance of secrecy and openness?" The corresponding objective of Paper 1 is "To identify the provisions around access and openness that attenuate or aggravate knowledge monopolies in collaborative biotechnology research projects." The objective of Paper 1 is narrower than the research question and focus on finding the provisions that enable governance. The question is posed with an underlying assumption that secrecy could be a part of such provisions.

5.1.3 Theoretical framework

The initial discussions on this paper began with the studies my co-author Egelie did on patenting and ethics for the CRISPR technology (Knut J Egelie et al. 2016; Knut J Egelie et al. 2018). Then we discussed the role of secrecy, and the entrepreneurial university's role and governance of innovation as well as the impact of public funding (Perkmann et al. 2013; Czarnitzki, Grimpe, and Toole 2015a; Mazzucato 2015; Van

Overwalle 2010; Bruneel, D'Este, and Salter 2010; Steinmo 2015). The third body of literature we considered was the contract and collaboration specific literature, such as (Sohn and Lee 2012; Lerner and Merges 1998; H. Stevens et al. 2016).

5.1.4 Main results and contributions

The method we use in the research is new to innovation studies: We analysed a large set of contracts, scoring the contract on a set of parameters. Such research is requested in the literature: Czarnitzki, Grimpe, and Toole (2015a) say *"…we did not find any studies that systematically analyse the contractual terms of scientific … contracts from state sponsors or private foundations*.". Further, Perkmann et al. (2013) comment that *"Records held by universities on industry contracts would represent an ideal source of information but are not readily available*". In that, for researchers, a result is that we demonstrate how to perform such research.

The results in terms of my research question on the societal utility of collaborative research are that we from the empirical results found a model that displays the possible societal utility ex-ante. In that, we present a contribution to policymakers, funding bodies and mangers for ex-ante impact assessment. Further, the ontological differentiation between access and openness, that includes secrecy, is important. As the previous literature tend to blend appropriation and publication into an overall term, our distinction may be useful for further research.

5.2 Paper 2

5.2.1 Summary

Title:

A New Advantage: Trade Secrets, Academic Secrets and Lead Time Advantages in Collaborative Research between Universities and Industry

Lie HT, Egelie KJ

Stated research objective in the paper:

«By abduction from our data, hypothesise how parties in university-industry collaborative research foresee the use of and agree on the related appropriation mechanisms trade secrets and lead time advantage, given the contracts being incomplete.”

Research design:

Review of the agreements of 52 collaborative research projects that allow for the use of trade secrets and lead time advantage, a subset of the projects from paper 3

Contributions:

i) An ontological clarification of “lead time advantage” and how it relates to trade secrets and other innovation appropriation mechanisms

ii) Empirical data from the agreements demonstrating the role of background trade secrets and the lack of an openness-confidentiality dichotomy

iii) “Lead time advantages” as a proposed framing for contractual agreements in collaborative research between universities and industry

Highlights:

Both industry and universities have secrets. Universities do not discuss academic secrets much. As secrecy in academia is normatively problematic, the research literature is mainly from the philosophy of science and ethics, and not empirical. Academic secrets secure priority in scientific publishing. Managers must, however, secure trade secrets needed for commercialisation in the early phase of innovation projects. “Lead time advantage” and trade secrets are preferred mechanisms by industry managers for taking ownership of innovation. Paper 2 discusses the literature on the appropriation of innovation and explains how lead time advantage is a composite concept that comprises trade secrets. It builds on an analysis of the agreements of 483 collaborative research projects between universities and industry. Surprisingly, Paper 2 find that only a small subset, 52 of the agreements, comprise trade secrets as a mechanism to appropriate innovation. After re-coding these agreements, the detailed contractual provisions are studied using cross-tabulations.

There are variations between industries, between types of research and the impact of background secrets. In the discussion, Paper 2 connects how appropriation mechanisms work, with both the commercial need for trade secrets and the universities' need for academic secrecy. Universities and industry appropriate innovation with a balance of openness and secrecy in their collaborations. Paper 2 develop hypotheses and conclude with a proposition on lead time advantage as framing for appropriation in collaborative research. The study concerns entrepreneurial universities as well as research managers and policymakers.

5.2.2 The research question of the paper related to the thesis' question

In Figure 5, I break the research question of the thesis on the management of trade secrets in collaborations into the overall question for the papers. In Paper 2, we ask how universities and industry can agree on secrecy in collaborative innovation. The research objective in the paper defines that we should use abduction and hypothesise, given the contracts being incomplete. Also, lead time advantages should be considered. The objective in Paper 2 is adapted to the journal where it has been submitted: Academy of Management Discoveries. This journal's mission is to "*publish phenomenon-driven empirical research that theories of management and organizations neither adequately predict nor explain".* The journal encourages abductive research, that is driven by surprises. The surprises that my co-author I had, came from realising that lead time advantages are a composite derivation of trade secrets and that these mechanisms are rarely included in the agreements we studied. However, they are the preferred mechanisms by industry.

5.2.3 Theoretical framework

The theoretical framework is the same as for Paper 1, with an addition of the idea of trade secrets being a major part of lead time advantaged. The theoretical foundation is from jurisprudence and Reichman (2011), as discussed in section 4.8.3.

As the research is abductive, the pragmatist philosophy of finding concepts that work is of importance. Peirce, one of the founders of pragmatism, used abduction as a tool for creating hypotheses. We do this in Paper 2 as a way of expressing what we find, and for future research to investigate further. However, we also use abduction, in line with the current use of the term, to justify our proposition of using lead time advantages as a concept in renegotiations (Douven 2017).

5.2.4 Main results and contributions

Paper 2 presents empirical data from the agreements demonstrating the role of background trade secrets when results may become trade secrets. Also, the data shows the lack of an openness-confidentiality dichotomy; there are levels of withholding and publication.

The paper presents an ontological clarification of "lead time advantage" and how it relates to trade secrets and other innovation appropriation mechanisms. This clarification is needed both for the literature on appropriation, but also for understanding studies building on CIS-data and the Oslo manual.

> As an example, not in Paper 2, the ontological wants may lead to an erroneous basis for policymakers: The European Union Intellectual Property Office (EUIPO 2017) reports to policymakers on the use of intellectual property in the EU. They define lead time advantages to include first mover advantage. The definition is in line with the Oslo Manual, but as discussed in Paper 2, will include trade secret use mixed with a marketing effect. The EUIPO study uses data from CIS and shows how firms combine trade secrets and patents. The study is thorough and confirms earlier findings on how firms use appropriation mechanisms: Managers mix and match depending on factors such as industry, firms size and openness. The study concludes that "*The analysis of the usage of IP bundles (in combination with other appropriability mechanisms) could be undertaken using the CIS data: complementarity [of patents and trade secrets] with trade marks and designs, lead time advantages and complexity of products.*" As Paper 2 demonstrates, complementarity cannot easily be found from the CIS data, as "lead time advantages" and "complexity" are composites

already. A consequence may be that the EUIPO study reports mistaken importance of trade secrets.

Finally, Paper 2 presents a new "Lead time advantages" as a proposed framing for contractual agreements in collaborative research between universities and industry. Currently, the agreement terms are on "confidentiality" and "publication": Our suggestion is to replace these with lead time advantage and to renegotiate during the project.

5.3 *Paper 3*

5.3.1 Summary

Title:

Monopoly spotting –

an empirical study of research collaborations between universities and industry

Lie HT, Egelie KJ, Grimpe C, Sørheim R

Stated research question and objective in the paper:

"How is how the societal utility of collaborative research results affected by the governance of openness? Openness may depend on the industry or other project characteristics. Thus, our research objective is to empirically investigate if there are characteristics of the research projects that ex-ante of the research results, characterise the agreed openness."

Research design:

Using the tool from paper 1 to score and analyse the agreements in 484 collaborative research projects sponsored by the Research Council of Norway. Scoring of the consortium agreement for a Horizon 2020 project with the tool of paper 1.

Contributions:

i) The ontological differentiation between openness and access found in biotechnology projects from paper 1 applies to other industries as well

ii) A demonstration of the tool from paper 1 applied to innovation management and sustainability

Highlights:

Industry and universities engage in collaborative research often without a clear understanding of how open the research results should be. The contractual terms of the research project document agreed on openness. The terms also decide if access through licensing will be exclusive to a few, or available for the many in open innovation. However, collaborative research agreements are complicated with entangled terms. Paper 3 applies the method from Paper 1 for analysing such agreements in 484 publicly sponsored projects in different industries. Placing the projects in the method's two-by-two matrix, paper 3 finds that around 20 per cent of the projects, across all industries, have agreements that allow knowledge monopolies to form. The study finds a positive association between the openness of the research results and the projects that are climate and transport-related. For organisations, research managers and policymakers, the method can be used on a single project or a portfolio of collaborative projects to better align with research policy.

5.3.2 The research objective of the paper related to the thesis' question

Paper 3 builds on Paper 1, and the research question in the thesis is the same. In Paper 3 we have learnt from the work on Paper 1, and sets a broader objective, to empirically investigate if there are characteristics of the research projects that ex-ante of the research results, characterise the agreed openness. As we in this study have data from all technological industries in the Research Council of Norway's portfolio, we can investigate differences between industries. The research question in Paper 3 is limited to the openness variable.

5.3.3 Theoretical framework

The theoretical framework is the same as for Paper 1, with an addition of the research on sustainability and the innovation system, as discussed in (Schot and Steinmueller

2018). Also, we studied recent literature concerning platforms and ecosystems such as (Holgersson, Granstrand, and Bogers 2018; Jacobides, Cennamo, and Gawer 2018).

5.3.4 Main results and contributions

The title of Paper 3 presents the concept of “monopoly spotting”, building on the metaphor of bus, ship, satellite, aircraft and train spotting. Here the dedicated spotter consults time tables ex-ante to look for emerging vehicles, and then ex-post notes the impact of said vehicle’s presence in terms of characteristics such as direction, speed and timeliness. Paper 3’s main contribution is to confirm that the method from Paper 1 can be used across industries and exemplify that on a running project. Besides, Paper 3 connects the method of Paper 1 to the possible ex-ante orchestration of research projects and as a bottom-up way to address the need for more sustainable research.

5.4 Paper 4

5.4.1 Summary

Title:

Trade Secret Management in SMEs

Lie HT, Tobro M, Hansen TB

Stated research question in the paper:

“We ask if there is a difference for SMEs between establishing and using trade secrets, both in numbers and in characteristics. We then ask if the SMEs use trade secrets for knowledge exchange through mechanisms such as licensing and innovation cluster participation. Finally, we ask if there are associations between SMEs establishment or use of trade secrets and management procedures.”

Research design:

We studied 3871 Norwegian SMEs that answered a survey on their use and management of intellectual property, including trade secrets.

Contributions:

i) We show that an ontological differentiation between establishing and using trade secrets is empirically founded.

ii) Trade secrets have a role both for SMEs' appropriation of innovation and for their sharing of knowledge in open innovation. SMEs share trade secrets more under the framework of contractual agreements, such as NDAs than under license agreements.

iii) SMEs that establish trade secrets tend to have procedures in place and participate in collaborations and innovation clusters.

Highlights:

SMEs use trade secrets to create competitive advantages from knowledge exchange and open innovation. Paper 4 builds on survey data from 3871 Norwegian SMEs with a novel set of questions: The study introduces a differentiation between establishing and using trade secrets. Paper 4 then uses innovation success proxies, built probit models and find associations with indicators of innovation, export, management processes, contractual agreements and revenue. The paper proposes how to set a baseline for future studies on the effect of the new EU and US legislation, and also contribute to management theory and practise on the SMEs' management of trade secrets.

5.4.2 The research question of the paper related to the thesis' question

In Figure 5, I break the research question of the thesis on the management of trade secrets in collaborations into the overall question for the papers. For Paper 4, I ask what characterises firms' establishment and use of trade secrets. Then I point to management procedures and possible engagement in open innovation as characteristics to explore. The research question in the paper details this in introducing main mechanisms in open innovation that formalises knowledge exchange that is licensing. However, the question also includes the more informal participation in innovation clusters where knowledge in form om trade secrets may float more freely under non-disclosure agreements.

Paper 4 does not investigate *how* the SMEs manage their secrets, but to what extent they appropriate innovations using secrecy, and whether the secret knowledge may be part of knowledge flow between firms. Paper 4, however, connects with the recent literature on *how* trade secrets are managed, such as (David Hannah et al. 2019; Robertson, Hannah, and Lautsch 2015; Costas and Grey 2014; Olander et al. 2015; Nelson 2016). Our connection here is that we quantitatively study to what extent the SMEs engage in procedures, agreements and collaborations concerning trade secrets. We also make a distinction between establishing and using trade secrets.

5.4.3 Theoretical framework

As an empirical paper, the main framework is the innovation studies' research on appropriability and trade secrets, such as (Capponi 2019; S.J. Graham and Hegde 2014; B. Hall et al. 2014; Levin et al. 1987). Paper 4 addresses open innovation more than collaboration, and thus we consulted the open innovation literature that also considers appropriation mechanisms or trade secrets, such as (Freel and Robson 2016; Al-Aali and Teece 2013; Laursen and Salter 2014; Bogers et al. 2017). We also build on a few SME-specific studies on appropriation and trade secrets that comprise (Delerue and Lejeune 2011; Leiponen and Byma 2009; Levine and Sichelman 2018).

5.4.4 Main results and contributions

We present data from an extensive survey of SMEs. In that respect, Paper 4 contributes to the literature with more data that future studies can consult. Then Paper 4 introduces a differentiation between establishing and using trade secrets and shows that it is empirically founded. Further, Paper 4 demonstrates that trade secrets have a role both for SMEs' appropriation of innovation and for their sharing of knowledge in open innovation. SMEs share trade secrets more under the framework of contractual agreements, such as NDAs than under license agreements. Finally, paper 4 suggests using the rate of licensing trade secrets as a baseline for the impact of the new EU and US legislation, rather than the perceived importance by managers.

5.5 *Paper 5*

5.5.1 Summary

<u>Title</u>:

Teaching Trade Secret Management with Threshold Concepts

Lie HT, Hokstad LM, O'Connell D

<u>Stated research objective in the paper:</u>

"Our research goal is to substantiate threshold concepts as a framework for teaching trade secret management, and to exemplify this with a curriculum outline."

<u>Research design:</u>

We list a selection of challenging issues in trade secret management based on our teaching experience. We indicate possible counterintuitivity and explore four areas using the threshold concept from educational sciences. We discuss how threshold concepts can be a useful framework for teaching trade secret management. We then present an outline of a curriculum suited for master's programmes and training of IP managers.

<u>Contributions:</u>

i) In trade secret management teaching simultaneities exist on a fundamental level in that openness and secrecy can be applied as characteristics of the same information.

ii) A curriculum based on threshold concepts suitable for advanced teaching of trade secret management

<u>Highlights:</u>

Trade secret management is an emerging field of research. Teaching trade secret management includes several challenging topics, such as how firms use secrets in open innovation. The threshold concepts framework is an educational lens well suited for teaching subjects that are transformative and troublesome. Paper 5 identifies four such areas in trade secret management and discuss how threshold concepts can be a useful framework for teaching. The paper then presents an outline of a curriculum suited for master's programmes and training of IP managers. The main contribution is to management and educational sciences. The study also concerns innovation studies and jurisprudence.

5.5.2 The research question of the paper related to the thesis' question

The main research question for the thesis is to explain the management of trade secrets in collaborations and open innovation. Teaching trade secret management as a topic is a test of the extent of possible explanation. For Paper 5, the specific research question concerns a curriculum for teaching trade secret management at master-level or to managers. The question came because of the practical need for a curriculum on teaching and training assignments.

5.5.3 Theoretical framework

First, this paper builds on the four other papers. Thus, the innovation and appropriation literature is extensive. Then the literature from educational science on threshold concepts was central, such as (A.L. Wright and Hibbert 2015; Land et al. 2005; J.H. Meyer and Land 2005; J. Meyer and Land 2006; Nicola-Richmond et al. 2018) and from economics (Davies and Mangan 2007). Also, some classics from the educational sciences had an impact on our study: (Schön 1987; Hunkins and Hammill 1994; Middendorf and Pace 2004).

5.5.4 Main results and contributions

The main contribution is a substantiation of threshold concepts as a framework for teaching trade secret management. The practical contribution to managers and teachers is an outlined curriculum that builds on threshold concepts.

6 Conclusions and implications

6.1 Main results as answers to the research question

The research question for the thesis is "*How are trade secrets managed in collaborations and open innovation?"*. The papers of the thesis give answers concerning collaborations in Papers 1 to 3, and for open innovation in Paper 4. However, Paper 5 summarises the answer in its conclusion: Trade secrets are managed in a *process of knowledge appropriation where well-defined trade secrets blend with other mechanisms.* The other papers contribute to this answer:

> In Papers 1 and 3 management of trade secrets is not an explicit topic, but openness and access are. The distinction that these papers introduce between access and openness, and the resulting model, is fundamental to trade secret management. As trade secrets must be managed from their conception, it includes the management of secrecy in the research phase of innovation. Papers 1 and 3 demonstrate how the managerial decisions on openness in the negotiations on the terms for collaboration affects the strategic positioning of the research results. When trade secrets are used for appropriation, the results can be categorised in the typology of the papers, as a "knowledge monopoly" or a "closed circle" and cannot be "open science". However, the contractual terms can regulate how and when the results move in this typology. Paper 2 indicates how trade secrets in the background information could lead to secrecy in the research results and connects the concept of lead time advantages to trade secrets. Here different mechanisms blend to create a lead time advantage as part for creating competitive advantages for the innovation.
>
> Paper 4 answers the question by empirically showing the difference in establishing and using trade secrets, compared with patenting. Further, Paper 4 address how SMEs prefer patents for licencing, both in the earlier and later stages of innovation, whereas trade secrets are used more in collaborations and participation in clusters. Thus, Paper 4 contributes with details on how SMEs use trade secrets in collaborations and open innovation.

The answer that managers in collaborations and open innovation mix trade secrets with other appropriation mechanisms confirm the results from (B. Hall et al. 2014). However, as discussed in section 1.1.2, B. Hall et al. (2014) do not decompose lead time advantages and complexity, as Paper 2 does. Thus, it is not clear from prior literature that secrecy is the main component of these appropriation mechanisms, as Paper 2 demonstrates.

6.2 Results from the epistemological objectives

In the chapter on the research design, I included ontological and epistemological objectives, in sections 4.5 and 4.6, Figure 10 and Figure 11. The ontological objectives were of use in the research process and in answering the research questions. However, the epistemological objectives led to a result on how to understand the body of knowledge this thesis encompasses. Papers 1 to 4 build on an understanding where trade secret management is a subset of innovation management and intellectual property management. The discussions and work on Paper 5 led to a shift, where trade

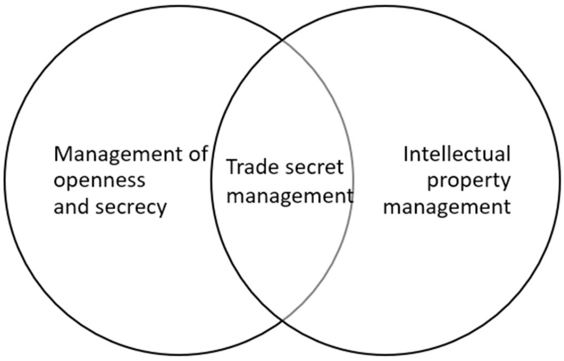

Figure 14 Trade secret management as an intersection

secret management is the intersection of intellectual property management and management of openness and secrecy.[34] This shift is coming from the understanding that Paper 5 makes clear: Trade secrets are mixed with other intellectual property and must be managed jointly with them. However, there is a special requirement: The knowledge governed by other intellectual property can be published, whereas trade secrets cannot. Nevertheless, by layering the information and using metadata, trade

[34] The management of openness and secrecy in an organisation includes privacy issues and cybersecurity, as well as strategies for knowledge search and sharing – see 1.1.4.

secrets can have a signalling effect in open innovation. As discussed in section 3.7, they can signal to potential open innovation partners that there is knowledge to be shared, that encourages mutual engagement in open innovation. Further, Paper 2 discussed the role of academic secrecy, and Paper 5 that of privacy. These aspects of secrecy and openness must be managed jointly with trade secrecy. From these considerations follows the epistemological understanding of trade secret management as shown in Figure 14.

6.3 Contributions to theory

All papers but Paper 5 have contributions to theory. Building on the review of formal and informal intellectual property in (B. Hall et al. 2014), this thesis contributes to theory with a more comprehensive view of how trade secrets are managed. With Paper 2, the thesis rebuts the normative typology the Oslo Manual has for appropriation mechanisms by showing lead time advantages as a mechanism with trade secrets as a component. Further studies that use surveys may now pose the questions on lead time advantages in a better way, and empirical results concerning trade secrets can better be analysed.

Paper 2 extend the selective revealing of firms discussed in (Alexy, George, and Salter 2013) to university-industry research collaborations, and suggest lead time advantage as an acceptable framing for negotiations. This contribution builds on the results from Papers 1 and 3. Paper 1 introduces an empirically based distinction between access and openness that is not apparent from prior literature. Paper 3 demonstrates that this distinction holds across industries. This distinction allows systematic analysis of contractual agreements in collaborative research projects. The distinction also allows for a more detailed analysis of the ex-ante strategic positioning of the projects, that can be compared to the results. Further, Paper 2 contribute to theory in that it connects the concept of incomplete contracts with the structure of the collaboration agreements, the choice of appropriation mechanisms and the framework for renegotiations.

Paper 3 explores openness in more detail than Paper 1 and shows that in collaborative research increased project budget associates with more secrecy whereas project coordination by university associates with more openness.

The distinction that Paper 4 introduces between establishment and use of trade secrets enables a more detailed view of the processes in open innovation. In addition to finding associations between use and establishment of trade secrets as dependent variables and proxies for innovation, Paper 4 indicates that for SMEs trade secret establishment and use associates with collaborations but not with licencing. That is SMEs share trade secrets more under the framework of contractual agreements, such as NDAs, than under license agreements. Further Paper 4 demonstrates that prior empirical studies on business managers' perception of the importance of trade secrets vary widely in results. A contribution in Paper 4 is the suggestion of using licensing of trade secrets as a baseline for assessing the effects of the changes in the legal regimes.

6.4 *The role of trade secret management in the future of innovation studies*

The next sections discuss further research. First, I point to how this thesis is relevant to future research areas in innovation studies. Then in the following section, I suggest further research from the different levels in this thesis. Finally, in section 6.6, I discuss limitations to my research and from that, options for further research. To demonstrate how this thesis is relevant to the future of innovation studies, I review how Martin (2016) presents "Twenty challenges for innovation studies". Seventeen of them relate to trade secret management.[35] There are brief comments to each of the challenges in Table 11. Below, I comment further on challenges 1, 9, 12 and 14, where I find that this thesis has most relevance. Table 11 demonstrates that a better understanding of trade secret management is an integrated part of future innovation studies.

[35] Ben Martin, Professor of Science and Technology Policy Studies, University of Sussex, is part of the NORSI faculty and introduced these challenges at a NORSI course «Innovation Research - From Origin to Current Frontier». The challenges have influenced the positioning of my papers.

Challenge		The relevance of the thesis
1)	**From visible innovation to 'dark innovation'**	Trade secrets are one of the concepts that are difficult to measure but are of importance. Papers 1, 2 and 3 deals with this challenge for university-industry collaborations. Paper 4 suggests how to measure SMEs use of trade secrets. Paper 5 and paper 3 points to how secrecy is understood, and thus paves the way for qualitative studies.
2)	From innovation in manufacturing to innovation in services	Services that build on software, big data and machine learning do include trade secrets. The algorithms that run the services are in many cases secret and includes a mix of technical and commercial trade secrets (Øverlier 2017, 46). Paper 4, figure 1 exemplifies this.
3)	From 'boy's toys' to the liberation of 'housewives'	No clear relevance.
4)	From national and regional to global systems of innovation	The trade secret legislation is harmonised between the USA and the EU. The index created by OECD gives a foundation for measuring the national systems and how they will converge (OECD 2015a). This is discussed in the introduction part, section 1.1.2 of this cover essay.
5)	From innovation for economic productivity to innovation for sustainability ('green innovation')	This is a central topic in Paper 3 and exemplified with a case.
6)	From innovation for economic growth to innovation for sustainable development	Paper 3 discuss how policymakers can use the two-by-two model in managing portfolios of research projects.
7)	From risky innovation to socially responsible innovation	The process resulting in the EU directive on trade secrets (European Commission 2016 (19) (20)) resulted in clear statements on the protection of free speech and the rights for whistle-blowers. This strengthens civil rights. This is a topic in Paper 5.
8)	From innovation for wealth creation to innovation for wellbeing (or from 'more is better' to 'enough is enough')	No clear relevance.
9)	**From 'winner take all' to 'fairness for all'?**	(European Commission 2016) emphasises the importance of trade secret protection for SMEs. Clearer legislation gives SMEs an important supplement to other IPR. This is a topic in Paper 4. Further, Paper 2 discusses how the ownership rights from appropriation by trade secrets, can be negotiated between collaborating parties.

10) From government as fixer of failures to the entrepreneurial state	If the state, and the universities, wish to engage in industrial relations, they must manage openness and trade secrets – as discussed extensively in Paper 2. The model in Paper 1 and Paper 3 is of use for ex-ante assessment of public funding.
11) From faith-based policy (and policy-based evidence) to evidence-based policy?	University policies, and research funding policy can be based on the factual use of trade secrets and the knowledge floor that creates, rather than views based on faith in the Mertonian norms. This is a topic of Paper 2.
12) Balancing the intrinsic tensions between intellectual property and open source	Trade secrets have an important role in knowledge exchange (Van Overwalle 2010; Von Hippel 1987; Hagedoorn and Zobel 2015). Paper 3 discuss this balance, as do all the other papers, as they bring in the balance between openness and secrecy.
13) Balancing the intrinsic tensions between exploration and exploitation	Trade secrets are a key appropriation mechanism, that is needed to bring innovation from the explorative to the exploitable. A strategy for innovation implies a strategy for IP (Al-Aali and Teece 2013). Paper 2 discusses how to use lead time advantages as a framing for collaborations that will go from exploration to exploitation.
14) Balancing the intrinsic tensions between closed and open innovation	An understanding the role trade secrets have for knowledge transfer is essential for the choice between closed and open innovation, e.g. as discussed by (Bernal 1939). This thesis demonstrates how trade secrets can be a part of open innovation, and question the secrecy-openness dichotomy, for example in Paper 2.
15) Balancing the intrinsic tensions between competition and cooperation	Sharing secrets build trust (Costas and Grey 2014). IPR management, including trade secret management, creates trust and knowledge sharing in collaborative teams (Olaisen and Revang 2017). Paper 2 includes this perspective.
16) Pricking academic bubbles	Notably, this challenge includes university-industry links and SMEs as example of possible bubbles. Both topics are important in this thesis. A question then is whether this thesis contribute to academic bubbles or pricks them, or both.
17) Avoiding disciplinary sclerosis	Secrecy is a factor in innovation studies but studied much less than the importance this thesis demonstrates. In innovation studies, the topic appears when appropriation mechanisms come on the agenda in the 1980'ies as discussed in Paper 2.
18) Identifying the causes of the current economic crisis	No clear relevance.
19) Helping to generate a new paradigm for economics: from Ptolemaic economics to???	Secrecy has a place in the understanding of evolutionary and behavioural economics, as shown by, e.g. (Castellaneta, Conti, and Kacperczyk 2017; Png 2017). The models for renegotiation and openness in papers 1 to 3, and the distinction between establishment and use in Paper 4 contributes.

20)	Maintaining our research integrity, sense of morality and collegiality	Secrecy's role in academia should be openly discussed. It has relevance for collegiality, as well as for the sharing and flow of knowledge, as discussed in Paper 2, and for reproducibility. Secrecy affects the interfaces of the research community to industry, military and government (Marx 2016; Maret 2016; Hables Gray 2016). Keeping secrets is a part of normal, organisational structures, and cannot be seen as inherently unethical (Costas and Grey 2014).

Table 11 The relevance of trade secret management to innovation studies, the ones in bold are commented further in this section.

From visible innovation to 'dark innovation': The term "dark" here concern the parts of the innovation system and processes that researcher know are there, but that is not understood, nor researched, because there are more convenient areas. Martin points to research that builds on patent or research funding data as areas that are well illuminated. All the papers in this thesis contribute to the illumination of new areas. Papers 1 to 3 develops and use a new method for assessing openness and access. Paper 4 explains the ambiguity of lead time advantages and the role of trade secret management for SMEs. Paper 5 brings epistemological contributions as to the perception of trade secrets and management, that is useful for further research on trade secrets.

From 'winner take all' to 'fairness for all'?: The new legislation in the EU and the USA have a levelling role in that SMEs are in a better position to use trade secrets in licensing. Also, secrecy has a levelling role in the balance between the knowledge that an employer can appropriate and the knowledge an employee can keep when changing employer. Knowledge spillovers, as well as licensing and knowledge sharing, are mechanisms that regulate the knowledge flow in society. Papers 1 to 3 model this flow in collaborations and show how policymakers and managers ex-ante may assess the flow and thus better regulate it. Paper 4 detail the decision mechanisms for managers of SMEs and suggests to policymakers how to assess the impact of the changes in the legal framework.

Balancing the intrinsic tensions between intellectual property and open source: The thesis, and Papers 5 discuss how secrecy and openness are part of the same continuum. Paper 3 has openness as the dependent variable, and Paper 2 introduces lead time advantages as a concept for mitigating the tension between publication and secrecy in collaborations. The discussion in this thesis builds on innovation studies literature such as (Alexy, George, and Salter 2013; Laursen and Salter 2014) and contributes with models and empirical results concerning the role of trade secrets, other intellectual property and openness. The foundation is the dual face of intellectual property, as shown in Figure 3: There is both control and dissemination.

Balancing the intrinsic tensions between closed and open innovation: The understanding of the dual face and the role of trade secrets is the also the foundation for the distinction between openness and access elaborated in Papers 1 to 3 and how Paper 4 points to trade secrets as a mechanism for SMEs in open innovation. Trade secrets have a role in both closed and open innovation. This thesis demonstrates the role of secrecy in open innovation and collaborations and thus contributes to the understanding of secrecy as a balancing mechanism.

6.5 *The levels of the study and further research*

The papers in the thesis mainly contribute to the levels of study as in Figure 15. The contributions can be a basis for further research.

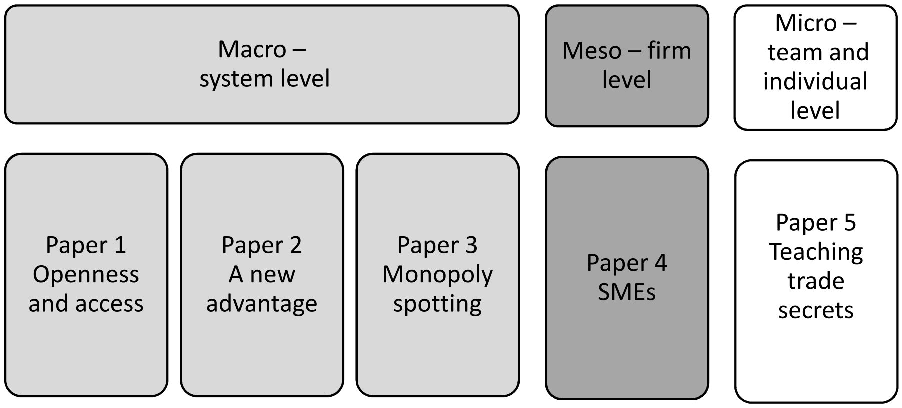

Figure 15 Levels and papers and chapter

At the system level, the two-by-two matrix from Paper 1 and 3, is a research contribution that follows the essence-part of Figure 3 Core aspects of appropriability adapted from Sun and Zhai (2018). The Dual face aspect, that appropriability is about both dissemination as in openness and governance as in access, is consistent with the two-by-two matrix model. Paper 3 shows how to ex-ante asses to what extent trade secrets enable “knowledge monopolies” and “closed circles”, and thus allow policymakers and managers to enforce or encourage openness and dispersed access. The model can be the basis for future innovation management tools, as discussed in Paper 3, that encompasses sustainability as part of the dual face of governance and dissemination. Further, the models for contractual negotiations and re-negotiations in Paper 2 is a research contribution that can be extended to management tools at the macro level. Papers 1 to 3 analyse contracts concerning agreements on collaborative research results between organisations. Further research could investigate if these models and tools could also be used within an organisation and for other types of agreements, and thus be more of a research method for the meso level and a tool for the management of organisations.

Paper 4 discusses the extent of support from empirical research for the recent legal changes in the USA and the EEA/EU. The recommendation to policymakers on licencing as a better baseline is a macro-level issue. Further research could build on that recommendation and find whether the change of laws leads to an increased flow of knowledge in society. On the firm level, the main contributions are a better understanding for managers and researchers on the inner workings of trade secrets and how they are combined with other intellectual property rights. We also show the associations between management practices, such as having procedures in place and the use and establishment of trade secrets. In that way, we confirm empirically the extent of the concept of bureaucratic secrecy appropriation mechanisms in SMEs (David Hannah et al. 2019). The empirical results are thus a basis for further research on how the procedures for trade secret management are formed.

On the individual level, Paper 5 contributes to new insights and a practical curriculum outline for teaching and learning trade secret management within the framework of threshold concepts. Future research could explore to what extent the framework improves learning for managers and students.

The key findings from this thesis could contribute to future theorising considering all levels and concerning innovation management in firms and research organisations. I referred to the Profiting from Innovation (PfI) framework in section 3.10. Intellectual property management is a part of PfI. This framework is not a theory of the firm in the terminology of economics. However, the addition of dynamic capabilities to PfI opens for the inclusion of the management of secrecy and openness. The concept of openness management could be a dynamic capability, as it comprises the identification of opportunities (as for choosing technology that is open or proprietary), the need for resources (such as for keeping something secret) and the structural and cultural impact from secrecy as a part of the organisation (Teece 2016, 2018a, 2017). This thesis could be the basis for a further investigation of trade secrets' role in research policy, business models, business strategy and innovation.

6.6 Limitations and further research

The thesis overall research methodology is the use of mixed methods in four different research projects with different data: The contract-study of Papers 1 to 3, the SME study in Paper 4 and the teaching paper 5. Thus, there is not a consistent research design, nor the same methodology in the papers, research methods or techniques for analysis. The lack of a consistent approach has been time-consuming and may have lowered the quality of the studies and the resulting papers.

For the contract study, Papers 1 and 3 demonstrate a new research method for studies of collaboration agreements. All the collaboration agreements are based on the framework of a single public sponsor and their projects. Further research on other portfolios could strengthen the new method and improve the scoring table with additional examples from other legal traditions.

The main body of research data, for Papers 1 to 4, is Norwegian. These studies use Norwegian collaborative research agreements and data from Norwegian SMEs. As intellectual property law is harmonised worldwide and business, in general, is harmonised in the EEA/EU, the results should apply outside Norway. Further studies with data from other countries may confirm that.

None of the papers builds on interviews. All Papers 1 to 4 are based on extensive archive studies of contracts, a survey and accounting data. Paper 5 uses multiple cases. Further research can build on these studies and include more qualitative data. As the thesis discusses, secrecy is a complicated topic both for individual, teams and organisations. Interviews are needed to confirm and detail the contributions of my research.

Bias in the research is that of formalism. Even though this thesis subscribes to pragmatism as a philosophy of science, management of intellectual property is to a large degree rule-based. I discuss that role in section 3.3, but not to the extent that the mindset of IP managers is explored in the research. The national and global systems for intellectual property, such as the patent system, is ridden with formalities that can hardly be understood by outsiders. Thus, for example, the trade secrets having a legal definition and the lack of such definitions of appropriation mechanisms in innovation studies may have impeded my ways of researching. It is also a strength, and perhaps a prerequisite for researching trade secrets, to be familiar with all aspects of intellectual property management, but for example, the points of view from ethics and organisational psychology could be underrated in the thesis. An example is that of trust. In Paper 2, trust is discussed, but it is not researched to any extent. Trust is a moderating factor to the formal procedures and agreements this thesis discusses at length. As an example, in the body of agreements we researched, we dismissed around half of the initial material we received. Some of the contracts lacked important pages, some could not be read from bad scanning - but a few were simple, one-page documents saying the similar of “the parties agree to research jointly and share the results”. As the sharing could be both publication or joint ownership or both, we could not use the case, and we dismissed it. However, the partners to that contract may have worked together over many projects and trusted one another, and thus could skip all formalities. The confidentiality terms of our project did not allow us to contact the projects, and thus we do not know. How trust works together with the management of trade secrets is a topic for further research.

6.7 Implications for policymakers

Research policymakers have attended to the needs of science in making policies for research funding and universities. This thesis supports research policymakers with methods to assess ex-ante portfolios of projects. Also, the models from this thesis align academic secrecy with trade secrecy. These models and the cited literature may be used for creating more flexible policies that take the new legal regimes on trade secrets into account to better utilise research results. An example is how the intellectual property policies of universities balance the requirements for publications and the norms of open science with their need for collaboration with industry. The two-by-two matrix from Papers 1 and 3 enables assessment of portfolios so that policymakers can observe how the policies work. Paper 2 provides a framework for negotiations between universities and industry without the current dichotomy of secrecy versus openness. This framework may be embedded in future policies for universities and funding bodies.

Further, the more detailed understanding of how SMEs establish and use trade secrets may inspire new policies for the public bodies that handle trade secrets. The national Intellectual Property Offices handle thousands of trade secrets every year, mainly in the form of patent applications. They have not developed services that utilise their capacity and competence in trade secrets. The new legislation in the EU and the USA should increase the use of trade secrets combined with patents, as Paper 4 indicate that ten per cent of the firms do. Thus, policymakers should consider new policies for the Intellectual Property Offices, such as the Norwegian Industrial Property Office and the European Patent Office, to provide businesses with relevant services for unpublished patent applications.

Finally, Paper 4 finds no association between licensing and trade secrets. An explanation could be that the lack of a legal framework has impeded such licensing. With the new legal framework and further legal harmonisation in the EU and the USA, the policymakers expect increased licensing of trade secrets. The benefits for SMEs, open innovation and the flow of knowledge were significant considerations for the new legislation. Paper 4 provides guidelines for measuring the impact of the new legislation.

6.8 Implications for practitioners

Paper 5 presents a curriculum for management of trade secrets. The curriculum demonstrates that intellectual property managers must acquire a new set of skills and understanding of managing trade secrets. These needed skills and understanding can be understood from Figure 14, where trade secret management is viewed as an intersection between intellectual property management and management of openness and secrecy. Examples of new skills are the management of privacy and cybersecurity.

Paper 4 concludes that trade secrets should no longer be regarded as an "informal" innovation appropriation mechanism, but as a mechanism that associates with procedures and co-exists with patents and other intellectual property. The distinction between establishing and using a trade secret comes from management practice, as exemplified in Figure 1. The results in Paper 4 confirm that the distinction. Thus, a manger that foresees trade secrets as an essential tool for controlling innovation and engaging in open innovation should consider supporting procedures to avoid loss of secrecy and misappropriation.

For practitioners, the implications of Papers 1 to 3 integrate with Paper 4. Licensing of trade secrets could be explored by managers to build competitive advantages in open innovation. If the innovation builds on collaborative research results, there is a link to the models in Papers 1 to 3. Research results as they become innovations can move from a knowledge monopoly to a closed circle and then open science. The exemplary case in Paper 3, demonstrates how the project managers and steering group can contemplate such strategic moves. The integration comes from how the understanding of openness in the business model develops and how trade secrets contribute to a lead time advantage. The eventual decision on a business model for commercialisation of the research result may be taken late, and the need for trade secrets for appropriation may change. Further, as discussed in section 3.1, the research results need not be either secret or open; they can be layered. Thus, it is possible to have the research results as open science, and still maintain control over the innovation by trade secrets in the further development of the innovation.[36]

This thesis provides insights to practitioners that may affect how a firm or organisation manage their engagements in open innovations and collaborations. When trade secrets are used for the appropriation of innovation, they must be managed jointly with other intellectual property, and in the view of secrecy and openness as a continuum.

Trade secrets are there not to be hidden and locked away, but to be used in *trade* –for signalling the competence of the firm, for searching and sharing in knowledge commons, for creating competitive advantages and ultimately for profiting from innovation.

[36] A typical case is that of a database with research results being published, or source code from the research becoming open under a permissive license. Then continued commercial exploration may create new additions that are kept as trade secrets.

7 References

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Part 2

Research papers

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Research paper 1:

Access and openness in biotechnology research collaborations between universities and industry

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Access and openness in biotechnology research collaborations between universities and industry

Abstract

Biotechnology research can spawn broadly useful technology research platforms such as CRISPR/Cas9, which has frequently been criticised as a knowledge monopoly. The access to such technology can be restricted, and utilisation of research results depends on the contractual provisions devised by the owners of the technology. It is therefore imperative to better understand the conditions under which knowledge monopolies are likely to emerge. Based on the analysis of 162 publicly funded collaborative research projects in biotechnology, we identify contractual provisions that govern the extent of access to and openness of research results. We evaluate how the project participants in free negotiations agree on ownership and user rights from intellectual property, as well as on confidentiality and publication rights. We develop a framework that identifies four cases – knowledge monopoly, attenuated monopoly, closed circle, and open science – that can help unravel the complicated contractual provisions and their interrelationships. The framework allows both policy makers and funding bodies to assess the likelihood of emerging knowledge monopolies ex-ante in order to assess the norms of open science versus the utilisation of the research results.

Keywords: knowledge monopolies, open science, publicly funded research, university-industry collaboration, biotechnology, access, openness

1 Introduction

Collaboration in research between universities and industry is essential for academic knowledge to be channelled into the industrial domain(Perkmann et al. 2013). Firms benefit from accessing complementary scientific knowledge that they can use to enhance the quality of their inventions, to realise efficiency gains for business R&D, and to anticipate future research problems in new technological areas(B.H. Hall, Link, and Scott 2003; Dasgupta and David 1994). There is evidence that industry participation in or sponsorship of academic research frequently limits the disclosure and further development of research results, methods, or materials. By delaying their public release, sometimes even beyond the time needed to file a patent, firms strive to secure private financial returns(Blumenthal, Campbell, et al. 1996; Cohen et al. 1998; Thursby and Thursby 2007; Joshua S Gans and Murray 2012; Czarnitzki, Grimpe, and Toole 2015b; Lerner and Merges 1998 Table V). Secrecy and the allocation of ownership and exploitation rights to firms in collaborative research may, therefore, jeopardise the norms of “open science”. These norms support an efficient and welfare-enhancing paradigm for creating a cumulative, reliable, and publicly available stock of scientific and technical knowledge(Dasgupta and David 1994; Mukherjee and Stern 2009).

Recent developments suggest, however, that firms may not be the only ones promoting secrecy and decreasing support of open science. Since the Bayh-Dole Act in the US and similar legislation in most European countries have come into force several decades ago, universities increasingly seek glory in both academic research and successful commercialisation of research results(Perkmann et al. 2013). To do so, they need control over the intellectual property (IP). Patenting the research results, or keeping them secret, may however lead to knowledge monopolies in broadly useful technologies. Patents that emerge from winner-take-all races are not only likely to hamper downstream development; they can also encourage upstream duplication, which undermines the cumulative advances in scientific knowledge production(Rai and Cook-Deegan 2017).

The controversy around some of the essential patents on the CRISPR technology is one case in point(Rai and Cook-Deegan 2017). The University of California, Berkeley, and the Broad Institute have been in disputes in the US and Europe over patent rights associated with the CRISPR/Cas9 construct. They have also developed strong commercial interests by taking equity in start-up companies that seek to commercialise applications of CRISPR/Cas9 for which they have received exclusive licences from the universities(Knut J Egelie et al. 2016; Knut J Egelie et al. 2018). It seems provocative that research underlying the CRISPR technology was funded by the US National Institutes of Health, socialising the cost and risk of research while privatising the financial returns(Mazzucato 2015, 4/11). In that sense, the CRISPR/Cas9 case highlights the tensions arising from the changing mission of universities. At the same time, our understanding is limited to what extent research in biotechnology beyond the prominent cases leads to the emergence of knowledge monopolies. A substantial share of public funding targets collaborative research, i.e. consortia of universities, industry and other participants. It is pertinent to investigate the extent to which such research can lead to knowledge monopolies or variants thereof.

A requirement that most funding bodies impose on research consortia is that the partners involved in joint research set up a collaboration agreement that governs, among other aspects, how the partners seek to deal with research results and the associated IP in a way that complies with the rules and regulations put forward by the funding body(The Research Council of Norway 2019). In this study, we focus on the contractual agreements that the range of partners in research collaborations, which feature at least one university and one industry partner, have negotiated among themselves. These agreements usually remain undisclosed. Our study exploits a unique opportunity to gain an in-depth understanding of the negotiated outcomes specified in such contractual agreements. Based on an analysis of the full text of the contractual agreements of 162 biotechnology projects funded by the Research Council of Norway (RCN) in the period from 2009 to 2017, we code the provisions associated with the handling of IP. From this, we determine whether the outcome of a research project is likely to end in a knowledge monopoly. Specifically, we argue that knowledge monopolies that stifle open science are related to questions on access to and openness of research results. Prior research has typically lumped these two dimensions together in the absence of more detailed information. In that sense, we define access as the control over ownership and commercial use rights of research results while openness refers to restrictions in the flow of knowledge in terms of publication rights and confidentiality. Access and openness are typically intertwined dimensions. Concentrated or dispersed access as, for example, in the case of exclusive versus non-exclusive licensing, may go along with low or high degrees of openness as, for instance, in case of broad versus restricted publication rights or confidentiality provisions. In that regard, we seek to identify the provisions around access and openness, which attenuate or aggravate knowledge monopolies in collaborative biotechnology research projects.

2 Contractual agreements governing access and openness

The contractual agreements of research consortia are complex documents and the terminology used in prior literature to describe contractual provisions varies. For our study, we are interested in two dimensions. First, the agreements regulate the ex-post access to research results, specifying the ownership of the results as well as the distribution of the rights to all commercial uses of the IP. The background rights on IP that the parties bring to the project are important too, but they are typically not negotiated. It is uncontroversial that the party bringing IP to the project keeps that control. Second, the agreements regulate the openness of the research results, that is the conditions under which the knowledge may be disclosed, specifying provisions on confidentiality and publication.

Related literature, such as Lerner and Merges, uses the term “control rights” in their study of alliances between biotechnology and pharmaceutical firms(Lerner and Merges 1998). Some of these control rights concern our understanding of access, such as patent ownership and the use rights, while others refer to openness, such as the right a party has to delay or ban publication. Contrary to Lerner and Merges, our study is set in the early phase of innovation, in which some control rights are not yet relevant. Examples include the right to manage clinical trials or to market the product. Also, the term “control rights” emphasises the need a private sponsor of outsourced research has to protect that investment. In our setting of publicly sponsored university-industry collaborations, an objective for the collaborations is the best public utilisation of the results. The collaborating partners are more in need of access to the results than control over the other partners. A more suitable terminology is in a study from Stevens et al. that concerns early-phase research in public-private partnerships. The authors use “access rights” related to use rights of background, sideground (results that are outside the scope of the project) and foreground (the results within the scope), and distinguish them from ownership(H. Stevens et al. 2016, 507). Following Stevens et al., our understanding of access concerns both ownership and use rights. Ownership refers to the ability to control and manage access to the IP while use rights are more condensed and mostly refer to the opportunities for commercial utilisation, both exclusively and non-exclusively, as well as the right to use the IP for further research.

Insights from prior literature on the access to research results and IP have been mixed. For example, while Walsh et al. document an increase in patents on the inputs to drug discovery, they find few indications that university research has been hampered by concerns about patents on research tools(Walsh, Arora, and Cohen 2003). However, Lei et al. conclude from a survey of agricultural biologists that IP protection of research tools has a strongly negative effect(Lei, Juneja, and Wright 2009) on access. From another point of view, Egelie et al. discuss the positive role of IP in view of the ethical obligations universities have for giving access to research platforms such as CRISPR(Knut J Egelie et al. 2018). More broadly, a study on research consortia in the life sciences concludes that the consortium partners' policies on IP often lack transparency, with few having clear and defined frameworks, which in turn impedes the access to IP(H. Stevens et al. 2016).

Moreover, prior research has frequently documented that industry as a sponsor of academic research or a partner in collaborative research often prefers secrecy over disclosure to increase the appropriability of the returns to the research performed(Blumenthal, Campbell, et al. 1996; Cohen et al. 1998; Thursby and Thursby 2007; Joshua S Gans and Murray 2012; Czarnitzki, Grimpe, and Toole 2015a; J.A. Evans 2010). Publication of the results may be delayed or banned in parts in exchange for the contribution that industry makes to the research project(Blumenthal, Causino, et al. 1996, 1737; Czarnitzki, Grimpe, and Toole 2015b; Blumenthal et al. 1996). The agreements in our study confirm that some projects may have provisions for keeping research results secret, see Figure 3: Description of the contractual provision measures. Conversely, universities and the individual scientists have historically had a strong interest in disclosure through publication. Merton famously characterised the modern scientific system as distinct from other social systems due to the importance of sharing(Merton 1973). Because of the enactment of Bayh-Dole and similar legislation in other countries as well as the proximity of science and technology in disciplines such as biotechnology, the attitudes of universities and university scientists towards disclosure versus secrecy have become less straight-forward. In that sense, universities may – similar to industry – show an interest in using various IP rights such as trade secrets or patents to appropriate the results from collaborative projects(Petrusson 2016, 415,421).

The two dimensions of access and openness suggest that the contractual provisions in research projects, therefore, imply the existence of variants in how knowledge and IP are handled, ranging from knowledge monopolies with concentrated access rights and low openness at one extreme, to open science at the other. Figure shows a simplified account of such variants, depending on how they score regarding their contractual provisions on the two dimensions of access and openness. Collaborative projects differ in the extent to which the ownership and use rights are either concentrated or dispersed. Concentrated access describes a situation in which one or a few of the collaboration partners own the results and have the exclusive use rights, while non-exclusive licencing indicates dispersed access. Research projects also differ on the degree of openness, that is the extent to which the contractual provisions allow research results to be kept as trade secrets or require that the results are disclosed and published.

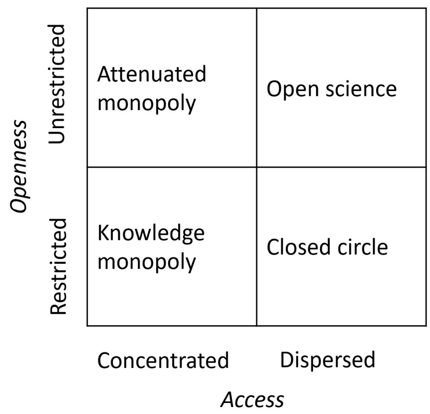

Figure 1: A model with access and openness

We argue that a "knowledge monopoly" can emerge if access rights are concentrated and if the openness of research results is low. In this case, the ownership and use rights lie in few hands, all licencing is exclusive, and there are trade secrets and publication restrictions. There may be limited licensing opportunities for organisations outside the focal collaborative project. Moreover, secrecy is prioritised over disclosure, possibly even beyond the time needed to file a patent. In a second case, contractual provisions may stipulate concentrated access rights while making knowledge public and easily searchable. We refer to this situation as an "attenuated monopoly" in which knowledge is controlled with IP rights, but published and open. Here, the openness provisions would likely reduce the extent to which upstream research may be duplicated. As there is no secrecy, the typical appropriation mechanisms are patents, material transfer agreements, database rights and copyright for software. A third case that we refer to as “closed circle” is described by a non-exclusive dispersion of access rights while openness remains low. This case may, for example, refer to a research result, such as a proprietary source code, that remains under non-disclosure agreements, yet is licensed out to those who ask for it. “Closed circle” resembles the concept of “club goods” from economic theory(Brandl and Glenna 2017). Finally, a combination of dispersed access and high openness leads to a situation that is within the norms of “open science”. It comprises use rights for all that ask, for example under licenses similar to open-source software. In addition, the research results are well-documented, publicly available and searchable. A university could, for example, provide access for anyone wishing to utilise a technology, with a non-exclusive licence on non-discriminatory terms. Such licencing is for example how the recombinant DNA and the co-transformation of eukaryotic DNA were transferred from the universities involved in the research(Knut J Egelie et al. 2016; Cook-Deegan and Heaney 2010).

3 Data and methods

3.1 Data

Our study uses data from 162 biotechnology research projects co-sponsored by the Research Council of Norway (RCN) over the period from 2009 to 2017. Every year, the RCN provides research funding of about 1 billion euro to projects spanning all areas of technology and scientific disciplines. Our sample is drawn from a total population of 21,838 projects that received public funding during that period. We restricted our sampling to those projects in the field of biotechnology that included at least one university and one industry partner. From these, we randomly selected projects for inclusion in the analysis. We excluded projects with insufficient information on variables of interest. The Norwegian Ministry of Trade, Industry and Fisheries and the RCN allowed us to research data on participants, funding amounts, and the collaboration agreement documents that the partners signed with the RCN and with each other. The share of funding provided by the RCN to these projects varies between

22% and 100%. In total, there are 1348 agreements among the partners of the 162 projects. That is, there are typically multiple agreements per project. The agreement documents are our sole source of information on the contractual provisions between project partners.

The collaboration agreements are comparable in length and structure. They are governed by RCN's contract management, including policy documents, the general terms of funding, and are based on several templates, or "boilerplate" agreements for collaborative research projects. While agreements based on RCN's contract templates represent 59% of the projects in our data, the collaboration partners are free to introduce new provisions or to modify the suggested provisions.

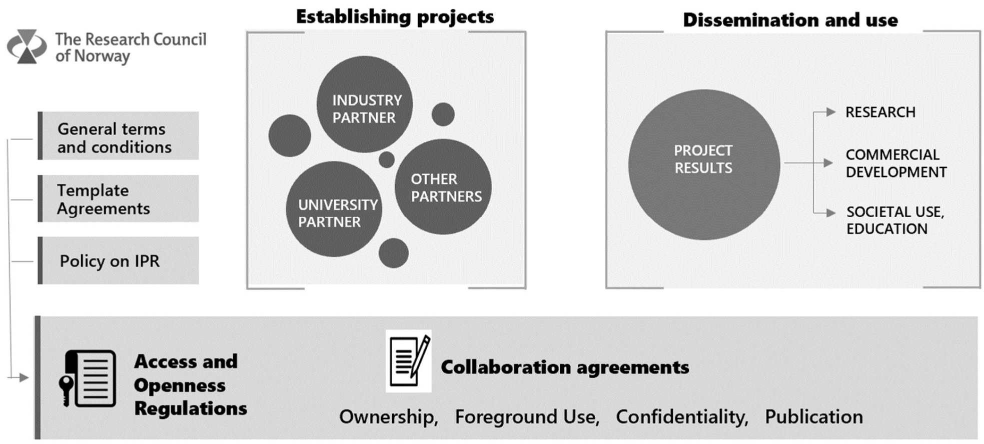

Figure 2: The RCN contract management and our study

Figure 2 shows the RCN's rules and regulations that provide a framework for the contractual provisions. However, the parties negotiate freely. Except for some aspects involving the distribution of rights in the projects, the RCN does not have special requirements for the scope, format or content of the collaboration agreements. The collaboration agreements are drafted in the initial phases of the project and govern the mutual rights and obligations of the project coordinator and the other partners in the project. The RCN communicates directly with the project coordinator only and is not a contractual party to the collaboration agreements. In our sample, 30% of the projects were coordinated by industry, 31% by universities or university hospitals and 38% by research institutes. The role of being the project coordinator does not necessarily reflect a stronger position in the negotiations of the terms but rather indicates administrative capacity or requirements. The coordinator may choose to have a multi-lateral or joint agreement or individual and bi-lateral collaboration agreement with each partner. In our sample, 73% of the projects had jointly-signed multi-lateral collaboration agreements. Each project partner is responsible to the project coordinator, and the coordinator is responsible to the RCN(The Research Council of Norway 2019). Our analysis does not extend to evaluating actual project results, only the intentions of the partners as stipulated in the contractual provisions.

3.2 Variables and measures

3.2.1 Contractual provisions

The measurement of contractual provisions regarding the access to and openness of research results from publicly funded research projects is implemented using a coding scheme applied to the collaboration agreements of the consortia. We developed the coding scheme in an iterative process, starting with an initial investigation of the common terms and expressions used in the agreements. We compared them with common clauses, terms and terminology used in templates of the RCN as well as other funding organisations in the European Research Area(The Research Council of Norway 2019; H. Stevens et al. 2016; DESCA 2017; Sohn and Lee 2012; Kretschmer, Singh, and Meletti 2018; Eggington, Osborn, and Kaplan 2013). Our scheme contains a similar set of IP related provisions as found in Stevens et al.(H. Stevens et al. 2016 Box 1, p.505). We noted that the terms and level of detail used in European contract templates are different from contracts used in the U.S. and the provisions of the Bayh-Dole act(O'Connor, Graff, and Winickoff 2010 ; Lerner and Merges 1998, 142-146). However, the terminology used in both Europe and the U.S. allows a distinction between access rights and openness, which we introduced in Figure 1: A model with access and openness.

We focus on four sets of contractual provisions that, while not entirely independent from each other, can be identified and delineated; provisions regarding the ownership of research results, provisions affecting the distribution of control rights to the commercial use of IP, provisions regarding dissemination and publication of project results, and provisions influencing the degree of confidentiality. Next, we scored the relative strength of each of the four sets of provisions based on pattern similarities in formulations of contractual terms and language. Table shows the coding scheme. The formulations do not necessarily reflect actual formulations in the collaboration agreements but rather group similar and comparable formulations in order to reduce the degree of complexity that the study of idiosyncratic contracts involves.

	ACCESS		OPENNESS		
	Ownership	**Commercial use rights**	**Publication**	**Confidentiality**	
1	Industry partner owns all IP and project results	Industry partner has exclusive use rights to all commercial use of IP and project results	All dissemination of project results is strictly controlled. No publications allowed	All information is by default confidential if not already public. No specified timeframe or other limitations	1
2	A specific party owns project results if based on own background, dominating contribution or own commercial interests. Otherwise jointly owned	All parties have by default exclusive use rights within specified field or non-exclusive, world-wide, royalty free in all fields	Project results must be published but could be delayed according to participants' needs	All project results and background information disclosed are by default confidential if not already public, limited in time	2
3	All project results are jointly owned. Separate agreements for commercial use rights	All parties granted non-exclusive use rights to all project results to be able to utilise own project result	Results shall be published, but publication must be sent to steering committee which could object and request modifications before publication	Project results and background information are confidential if marked, justified and limited in scope and time	3
4	A specific project partner retains ownership of all project results. Where several parties have carried out work generating project results and where share of the work cannot be ascertained, they have joint ownership	All parties have royalty free use rights, but only during the project period to results that are needed to utilise own project result. Further use rights may be given upon request	Publications could be delayed due to patenting or other justified grounds, but according to national laws. Clearly stated that results must be published within a time frame	Project partners have to specifically request confidentiality. Information must be marked confidential, time limited and approved by steering committee. Parties could refuse	4
5	Academic partner owns all IP and project results	Only academic partner has specified use rights to project results	No publication restriction. Specified that results must be published	No terms on confidentiality specified	5

Table 1: The coding scheme including typical contractual clauses

Next, two members of the research team experienced in the analysis of contracts jointly coded the agreements from 30 collaboration projects according to the coding scheme. They discussed their respective coding decisions as well as cases of doubt. In general, and mostly because many consortia used standard formulations from the templates, there were very few discrepancies in the coding decisions between the two coders. For that reason, the remainder of the agreements is coded independently, resolving cases of doubt through discussions.

In order to map the projects to the matrix described in Figure , we created two dummy variables measuring access and openness of the projects. The first variable, access, is assigned a value of one if the projects are coded as having dispersed ownership or dispersed use rights (i.e. commercial rights to use of the foreground, the research results) and zero otherwise. All other codings in Table either indicate concentrated ownership and use rights on the side of the industry or university partners, or they lean towards concentration. The variables for publication and confidentiality can be understood as ordinal. We create the second dummy variable, openness, by running a factor analysis to aggregate the two variables. Both variables are positively correlated (r=0.4558) and load highly on a joint factor variable (r=0.8532). The factor variable (with a mean of zero and a standard deviation of one) accounts for 72.79% of the variance. Subsequently, we split the variable at and including the median to create a dummy variable that measures the openness of a project's research results. The variable takes the value of one if the factor variable score is higher or at the median and zero otherwise.

3.2.2 Project characteristics

We define several other variables describing project characteristics based on information provided by the RCN. First, we count the total number of partners in a project as well as the different types of partners, showing the share of firms and the share of universities in the projects. Next, we use the RCN funding share as a variable that measures the share of the total project budget that was sponsored by the RCN. We also create dummy variables, measuring whether the project coordinator is a university or not and whether the project type can be characterised as "research" as opposed to "commercial" or "other" as indicated by the RCN. Moreover, we measure the total project budget in millions of NOK.

3.3 *Empirical approach*

Our empirical analysis starts by presenting four exemplary projects out of the 162 projects to illustrate the different concepts depicted in Figure . Next, we show descriptive evidence on the 162 biotechnology projects under study. We then present the results of an analysis of variance (ANOVA) on the project characteristics variables that we compare by group.

4 Exemplary cases

Due to the confidential nature of the agreements, we do not reveal details on the contracts and their contractual provisions while mapping them to the four cases in Figure . The cases are from our sample but anonymised.

4.1 *Knowledge monopoly – project "Medical imaging"*

This project is an innovation project with a budget of around 4 million euro. The RCN funds around one-third of the project. It runs over several years and is composed of two universities, three industrial partners (all but one from Norway), and research institutes. One of the industry partners serves as the project coordinator. All results are owned by the coordinator, and all commercial use rights are exclusive and to be used by the coordinator. Moreover, all publications are controlled by the coordinator who also has the right to request changes of any manuscript before publication. The results are a mix of applied research and commercial results to which the coordinator has privileged access.

4.2 *Attenuated monopoly – project "Energy from biomaterial"*

This project is a large environmental research project with a budget of more than 10 million euro. The RCN funds about half of the project. The project runs for almost a decade and has five university partners and around 20 industry partners, most of them from Norway. There are also research institutes involved, one of which is the project coordinator. All results are owned by the coordinator, and all commercial user rights are exclusive and to be used by the coordinator. Even though the publication of the results is allowed and encouraged, the clauses on confidentiality are strict. The results are a mix of basic and applied research as well as commercial results. In that sense, the contractual provisions point towards concentrated access while allowing for somewhat controlled dissemination.

4.3 *Closed circle – project "Prevention of fungal infections"*

This project can be characterised as a larger innovation consortium comprising only two university partners, but many industry partners and some institutes. The total budget of the project is about 5 million euros of which the RCN is funding half. It runs for only two years. One of the industry partners coordinates the project. The ownership of research results would be either by one partner if created by that partner alone or jointly owned otherwise. All partners shall have access to the commercial use of results if desired. Publication is desired and encouraged, but the steering committee can impose publication delays to facilitate the protection of IP or if the commercial value of the project result could be reduced.

4.4 *Open science – project "Food and plant production"*

This project has four participants, one university, two industry partners and one institute; all are from Norway. It has a budget of around 5 million euros of which the RCN funds around 80%. The institute partner is the project coordinator. Each participant is granted ownership rights and all IP to project results produced by participants individually. Project results shall also be published as soon as possible. The objective of the project is to create and explore different research tools without concrete considerations for innovation and commercialisation. In that sense, the contractual provisions closely follow the norms of open science.

5 Results

In a first step, we are interested in characterising the RCN funded biotechnology projects regarding their contractual provisions to determine their approach to access and openness of research results. Figure 3 shows descriptive statistics. With regard to the ownership of research results, we find that in most of the cases ownership tends to be concentrated with the university partners (categories 4 and 5, i.e. 61%) or the industry partners (categories 1 and 2, i.e. 25%). Joint ownership is rather uncommon, as it is only used in 14% of the projects as the intermediate category shows. Concerning the distribution of use rights, we find that joint use rights are the dominant mode with about 46% of the cases. Exclusive use rights for the industry partners (categories 1 and 2, i.e. 28%) and university partners (categories 4 and 5, i.e. 25%) are relatively less frequent. The indication is that, while ownership is typically concentrated, use rights are more dispersed. Combining the two variables, we find that in 51% of the projects there are either joint ownership or joint use rights. Turning to the contractual provisions regarding publication and confidentiality, we find that both variables for most projects show intermediate values, indicating that most projects include some confidentiality clauses and publication restrictions.

Access	Openness

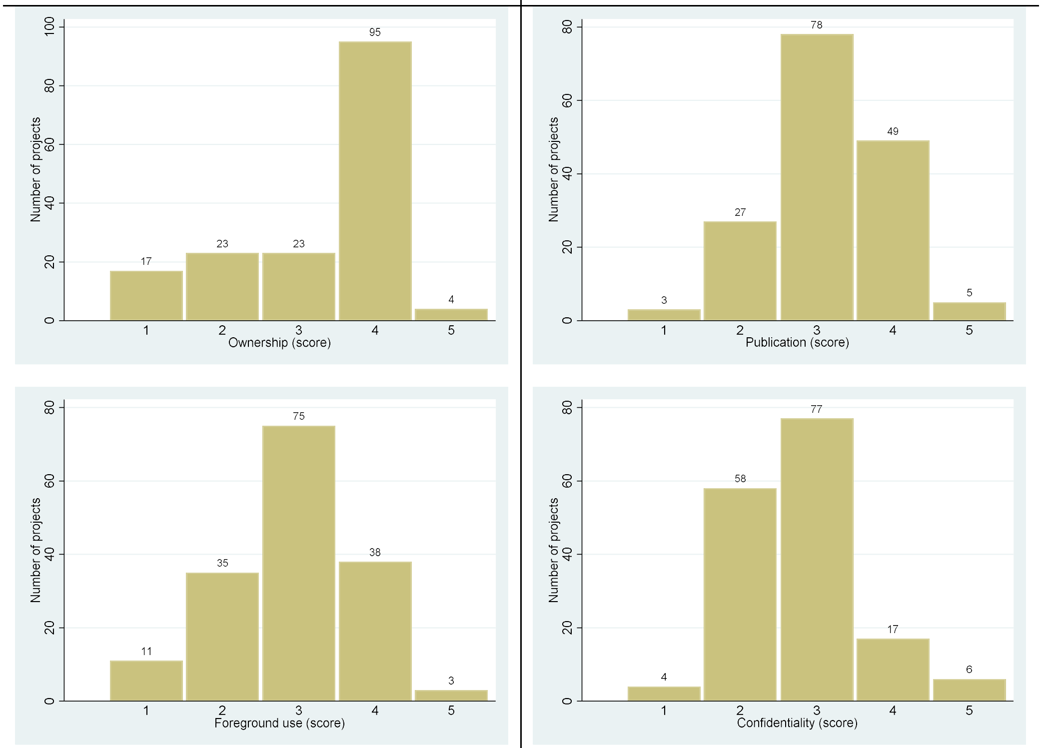

Figure 3: Description of the contractual provision measures

Next, we cross-tabulate the two dummy variables on access and openness that are based on the four types of contractual provisions.

Figure 4 shows the results. We find that 17% of the projects are characterised by contractual provisions increasing the likelihood of the emergence of knowledge monopolies. In contrast, 32% of the projects feature contractual provisions that resemble more the principles of open science. The remainder of the projects is characterised by either restricted openness or concentrated access. The attenuated monopoly, featuring contractual provisions that indicate a high degree of openness, yet concentrated ownership, includes 32% of the projects while the closed circle, characterised by low openness but dispersed access rights, includes 19% of the projects.

Openness	Access: Concentrated	Access: Dispersed	
	80 49.4%	82 50.6%	162 100%
Unrestricted	Attenuated monopoly **52** **32.1%**	Open science **52** **32.1%**	104 64.2%
Restricted	Knowledge monopoly **28** **17.3%**	Closed circle **30** **18.5%**	58 35.8%

Figure 4: Cross-tabulation of access and openness in RCN funded biotechnology projects

To better understand the characteristics of the projects in the four groups, Table 2 shows the results of an analysis of variance (ANOVA) for the project characteristic variables differentiated by group. It turns out that most differences in mean values, while informative, are statistically insignificant, indicating relatively small differences between the groups. We find that projects in the knowledge monopoly group are the smallest by the number of partners involved in the project, even though closed circle projects are the smallest by total budget. Projects in the attenuated monopoly and open science group are the largest, both by the number of participants and the total budget. The institutional composition of the projects in the four groups is virtually invariant. All groups feature about the same share of firms as well as universities among the project partners. Concerning the funding share sponsored by the RCN, knowledge monopoly projects exhibit the lowest while closed circle and open science projects show the highest amount of public funding. Projects also more often feature contractual provisions regarding open science when they are coordinated by a university partner and when the project itself is funded as a research project as opposed to a development and commercialisation project.

Variable	Mean (Std. Dev.)				df	F	Prob>F
	"Knowledge monopoly" (n=28)	"Attenuated monopoly" (n=52)	"Closed circle" (n=30)	"Open science" (n=52)			
No. of partners	6.54 (3.77)	9.44 (5.58)	7.50 (3.54)	8.63 (4.61)	3	2.70	0.0478
Share of firms	0.51 (0.18)	0.52 (0.20)	0.49 (0.24)	0.50 (0.20)	3	0.18	0.9107
Share of universities	0.34 (0.18)	0.31 (0.21)	0.31 (0.18)	0.34 (0.20)	3	0.29	0.8352
RCN funding share (%)	57.95 (22.05)	63.81 (20.19)	70.19 (22.68)	66.90 (22.75)	3	1.72	0.1649
University coordinator	0.25 (0.44)	0.31 (0.47)	0.23 (0.43)	0.40 (0.50)	3	1.13	0.3402
Research project	0.11 (0.31)	0.25 (0.44)	0.30 (0.47)	0.35 (0.48)	3	1.88	0.1352
Total budget (mNOK)	24.12 (48.24)	37.98 (58.10)	19.05 (39.59)	36.58 (80.33)	3	0.84	0.4747

Table 2: Results of the ANOVA analysis of project characteristics

6 Discussion and conclusion

Knowledge monopolies in broadly useful technologies are problematic, no matter whether they are controlled by academia or industry because they likely hamper downstream development and encourage upstream duplication. Prior research has argued that monopolies undermine the cumulative advances in scientific knowledge production(Rai and Cook-Deegan 2017). With the caveat that the broad usefulness of newly developed technologies often only becomes apparent ex-post, our results indicate that publicly funded research does end in knowledge monopolies in a non-trivial number of cases. More importantly, we identify two variants of knowledge monopolies that may be equally harmful to follow-on research since they violate the norms of open science in one or the other form. Only about one-third of the projects in our sample subscribe to the norms of open science.

Our results hold two central insights. First, we offer a distinction between access and openness provisions that prior literature has often lumped together due to a lack of detailed information. This distinction allows systematic analysis of contractual agreements in collaborative research projects. The provisions on ownership, the distribution of use rights, publication and confidentiality, are standard elements in these types of contracts. However, their concurrence leads to different situations concerning the handling of IP in the projects, which in turn holds different implications. It is a long-standing belief that patents and other IP rights limit researchers' access to breakthrough technology(H. Stevens et al. 2016), (Henry and Stiglitz 2010; B. Andersen and Konzelmann 2008). Our research supports an important qualification. We find that it is not the IP rights that restrict access but how organisations manage IP. They provide access through licenses and other types of agreements as in the case of collaborative research. Openness of the research results, i.e. disclosure and publication, factor in too. In that sense, our analysis paints a more complex picture of the reality of contractual provisions in collaborative research.

Second, our research has developed a tool that can be useful for funding bodies and policy makers. Contractual agreements can be designed and classified according to how they score with regard to access and openness. This allows stakeholders to monitor the projects. Those projects that likely lead to broadly useful technologies, similar to the CRISPR technology, could then be required to rework access and openness provisions in order to avoid knowledge monopolies. In that regard, the incentives of the universities behind the CRISPR technology to secure private financial returns could have been reigned in early by the funding bodies enabling the research in the first place. While the universities promised to allow other researchers access to the technology for academic purposes, the commercial rights are concentrated with a small number of firms in which the universities own a major stake. Several questions arise that so far have not been answered yet: What happens if other researchers make significant discoveries with commercial potential using a tool they were allowed to use for non-commercial research purposes? What opportunities do these researchers and universities have for the further use of the research results? Our conceptual model allows unravelling the complicated contractual provisions and their interrelationships in order to clarify issues like these up front and before engaging in collaborative research. Such pre-project planning could increase the quality of any collaboration agreement and, more importantly, allow for more transparent handling of IP for a funding body or society at large.

7 Data and code availability statement

The results were obtained using the STATA SE Version 15.1 statistical software package. The do-file can be obtained from the authors upon request.

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Research paper 2:

A New Advantage: Trade Secrets, Academic Secrets and Lead Time Advantages in Collaborative Research between Universities and Industry

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A New Advantage: Trade Secrets, Academic Secrets and Lead Time Advantages in Collaborative Research between Universities and Industry

<u>Abstract</u>

Both industry and universities have secrets. Managers must secure trade secrets needed for commercialisation in the early phase of R&D projects. Academic secrets secure priority in scientific publishing. “Lead time advantage” and trade secrets are preferred mechanisms by industry managers for taking ownership of innovation. We discuss the literature on the appropriation of innovation and explain how lead time advantage is a composite concept that comprises trade secrets. We then analyse the agreements of 483 collaborative research projects between universities and industry. Surprisingly, we find that only a small subset, 52 of the agreements, comprise trade secrets as a mechanism to appropriate innovation. After re-coding these agreements, we study the detailed contractual provisions using cross-tabulations. We observe variations between industries, between types of research and the impact of background secrets. In our discussion, we connect how appropriation mechanisms work, with both the commercial need for trade secrets and the universities’ need for academic secrecy. Universities and industry appropriate innovation with a balance of openness and secrecy in their collaborations. We develop hypotheses and conclude with a proposition on lead time advantage as framing for appropriation in collaborative research. Our study concerns entrepreneurial universities as well as research managers and policymakers.

<u>Keywords</u>: Innovation appropriation, appropriability, university-industry, research agreements, collaborative research, trade secrets, academic secrets, intellectual property management, trade secret management, appropriation mechanisms, lead time advantages

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1 Introduction

1.1 Secrecy and lead time advantage

Trade secrets can be the only way to appropriate innovation. Universities collaborate with industry to make research useful to society. The industry partners in a collaborative research project may find that trade secrets are needed to commercialise the research. Then the university partners should consider the societal benefits and could agree to keep those research results secret. Thus, we were surprised as we examined 3937 collaboration agreements between universities and industry in 483 technology-based research projects. We found that the agreements rarely prepare for the use of secrecy and lead time advantage, the innovation appropriation mechanisms that most business managers prefer over patents and copyright (Levin et al. 1987; B. Hall et al. 2014; Eurostat 2016). Our intuitive explanation was that academics normatively shun secrets. However, as we read more of the agreements and considered the options for commercialisation of the research, we realised that trade secrets must be managed from the very beginning of an innovation project if they are to be used for appropriation. If secrecy is the primary appropriation mechanism, then control of the innovation is lost if the secret is published. Thus, the industry partners should at least in projects identified as applied research, insist on trade secrets being defined in the contracts as a possible way of appropriating the research results. We hardly found projects with clear terms that allowed trade secrets. Lead time advantage is, from the literature cited above, an appropriation mechanism preferred by business managers. The lead time includes the time advantages of keeping competitors away, by intellectual property rights, including trade secrets, but also by pricing mechanisms or merely the time to set up production and sales. Unlike for trade secrets, there is no legal definition of a lead time advantage, and thus the term is not used in collaboration agreements. As we investigated the use of lead time advantages, we found that the concept mainly depends on trade secrets and is used ambiguously in the literature.

Trade secrecy law creates a sort of commons. Technological knowledge from competitors can legally be reverse engineered and then freely used. The same principle goes for commercial knowledge. It is legal to observe what competitors do, and for example, direct the marketing to the same groups as they sell to (Madison 2010; Reichman 2011). In that sense, there will be a time lag, a lead time before a competitor can understand the trade secret, which then stops being a secret. However, the initial innovation has a head start and the advantage of the lead time may remain for some time.

Firms may come together and share trade secrets, for example, the results from collaborative research. Also, this may be seen as a commons, though only open to the participants. It is what economic theory calls a "club" (Buchanan 1965) and what Knut J Egelie et al. (2019) coin as a "closed circle" with university-industry research consortia as the example. When firms and academic institutions collaborate, the management of secrets and the decisions on publication of research results become complicated. Our research goal is thus to hypothesise how parties in university-industry collaborative research foresee the use of and can agree on secrecy.

We contribute with an ontological clarification of lead time advantage and show how the concept relates to academic secrets, trade secrets and other innovation appropriation mechanisms. We present empirical data from the agreements that demonstrate the role of background trade secrets and question the openness-secrecy dichotomy. From this, we present hypotheses for further research and a proposition to explore lead time advantage as framing for contractual agreements in collaborative research between universities and industry.

1.2 Expectations and outline of the paper

The empirical results from our study show that around ten per cent of the collaboration agreements have provisions on confidentiality so that the industry partners could use trade secrets in their innovation. However, only two per cent had unambiguous contractual clauses that explicitly mentioned trade secrets as a possible appropriation mechanism. Since a lead time advantage lacks a legal definition, we did not expect to find any explicit clauses facilitating lead time as an appropriation mechanism. We did expect to find stipulations in the terms for publication of the research results. If the project participants envisaged that a lead time advantage could be useful in the innovation process, there should be mechanisms for delaying publication, in addition to those needed for patenting. We rarely found projects with terms preparing for lead time advantages in the utilisation of the research results. For the around ten per cent of the projects where secrecy and confidentiality are connected to the utilisation of the research results in innovation processes, we present data on the agreed delay of publication and the use of confidentiality terms for background and research results.

We begin with setting our frame of reference and discussing the literature on appropriation mechanisms. We here explain trade secrets, academic secrets, and how they relate to lead time advantage before the empirical part of our study. We present our data, how we coded the collaboration agreements and then the results in the form of cross-tabulations. Our discussion is extensive and conceptual as we connect several of the mechanisms we observe. Thus, we connect with more theory as our discussion advances. We finally give directions for further research in the form of hypotheses and a proposition on the use of trade secrets, academic secrets and lead time advantages in collaborative research.

2 Frame of Reference

2.1 *Search and the balance between openness and secrecy*

A club or closed circle that share secrets resolves the need for search of knowledge. This is part of the rationale for joining a collaborative research project. The benefit is access to knowledge. A cost is in the possibility that valuable knowledge is revealed to a future competitor. An academic institution may find that there is no such cost, as all knowledge they produce is to be published. Alexy, George, and Salter (2013) discuss how firms use selective revealing and the implications for open innovation and management practice. Selective revealing may be used to manage collaborative engagement, and thus be a part of how the firm searches for new knowledge. Contractor (2019) shows how there is an optimum level of disclosure, whenever disclosure is not *the* strategy, as it is for open source software and creative commons projects.

Innovation managers then need to set a revealing strategy, that is, to manage openness and secrecy. Openness may contribute to the firms' ability to search. However, in a closed circle, such as a research collaboration can be, secrecy can be used as a mechanism for sharing knowledge among the members, enabling them to control an emerging innovation. Such secrecy can be acceptable to both university researchers and firms. Sohn and Lee (2012, 545) present an interview-based conjoint analysis from South-Korea on how university researchers and firm managers see the terms of collaborations agreements given ownership, publication, liability and remuneration. They find that both sides agree that publications should have consent from the firms and that requirements for confidentiality have priority over publication. Czarnitzki, Grimpe, and Toole (2015a) have a similar conclusion in a survey of German scientists. Industry sponsorship more than doubles the probability for secrecy and delay of publication. Such delay is problematic to academic researchers where priority is essential, that is to be the first to publish. However, secrecy is not something required only by industry. Academics do keep secrets, to be the first to publish (Bok 1982 ch. XI; Biagioli 2012). Academic secrecy is temporary, as the objective is to publish. We discuss academic secrets later and turn now to explain how timing interworks with secrecy.

2.2 *Secrecy timing and the concept of lead time advantages*

The secrecy required by industry to control an innovation can also be temporary, either from a revealing strategy or only by the secrets being found and published by others. Mansfield (1985) finds that trade secrets in average leak within 15 months, with the chemical industry as an outlier where secrets may last some years. Thus the selective revealing discussed by Alexy, George, and Salter (2013) becomes an even more attractive strategy, as secrets get out. The sparse literature on trade secret management, such as in the models of Bos, Broekhuizen, and de Faria (2015), do not address this pro-active revealing of secrets but instead assume that they get lost by leakage or parallel development by competitors. However, David R. Hannah, McCarthy, and Kietzmann (2015) present a typology for deliberate leaks. They connect this to the appropriability of innovation in discussing lead time with the high-profiled examples of Google revealing their advertising business model in 2004 and how video console makers, such as Microsoft and Sony leak the features of their new models in a cycle with informing the video game developers. Controlling the advantage from lead time, the head start of a new product, service organisation or business model innovation usually depend on secrecy mixed with other mechanisms.

However, lead time advantage is an ambiguous term. As a concept for product or service innovation, it means “the advantage of being early in the market with a new product or service and keeping the competitors away by that” (Von Hippel 1982, 109; Hurmelinna-Laukkanen and Puumalainen 2007). The term is close to but not the same as “first mover advantage” (Lieberman and Montgomery 1988, 1998), “market pioneer advantage” (W.T. Robinson and Fornell 1985) and “barriers of entry” (Demsetz 1982)[1]. The literature offers no conclusions about the nature of the advantage or how those advantages relate to other innovation appropriation mechanisms or concepts such as competitive advantage and profitability.

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[1] In process innovation, having an operational innovation view, or regarding “total quality management” or “lean processes” it could mean “the advantage from having short time from custom order to delivery” (Krajewski, Ritzman, and Malhotra 2013, 29,42) Interestingly the term is not used in the discussion of academic secrets. Possible academic lead time advantages would be more citations and funding.

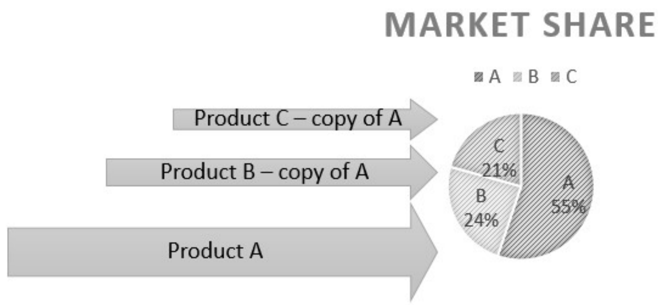

Figure 1 First mover advantage

We find three distinct types of time advantages referred to in the literature. The intuitive one is the “time-is-money” advantage, that is simply to launch a product as fast as possible. With a late market launch, possible sales are lost. Delayed income will delay the profit of the firm. Even if there are no competitors, being late in the market means lower profit that income year. Then, there is the “first mover” effect, where early launch may lead to a larger market share, as shown in Figure . Here “first mover advantage” means that imitators will have a lower market share. Product A is copied by B and C. However, A keeps a high market share because the market tends to prefer the first entrant. A lower market share does not necessarily mean a lower profit. The advantage is not from a lead time, but from a first move. As the innovation can freely be copied, the first mover advantage cannot be licensed in other ways than through branding.[2]

In Figure 2 product A is launched, and B and C wish to copy it. They react after a “response time”. However, they cannot copy A, because they do not understand how it works, that is there are trade secrets, or there are risks of intellectual property infringement, such as for patents. B and C remain in the R&D lab, and A enjoys a lead

[2] See references in APPENDIX A. For licensing there is a need for a legal object of the license. For the first mover advantage example, as B and C legally copies A, there is nothing that A can license to others, but their reputation and quality. Typically, that is appropriated by branding with a registered trademark.

time advantage with a 100 per cent market share, being a unique product until the secret is revealed or the patent term expires – or a substitute product is developed. The lead time advantage can be licensed by the use of any intellectual property right, including patents, trademarks and trade secrets. In the simplest theoretical case, the lead time advantage concept is only the advantage of holding a trade secret, for example, the production method, until the secret becomes public and is copied. In a real case, the trade secret may not ultimately hinder copying, but could, for example, reduce production cost or increase quality.

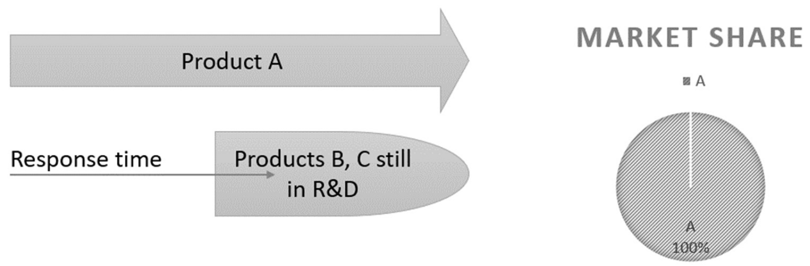

Figure 2 Lead time advantage includes response time

When managers are asked about their use of appropriation mechanisms in surveys with questions using the term lead time advantage, it is not clear which concepts they consider, as the prior literature mixes "time-is-money" and first mover advantages into lead time advantages. As an example, the Oslo Manual (OECD/Eurostat 2018, 115) merges these concepts defining them as "rapid introduction of product or business processes". Von Hippel (1982, 110 and fn. 16) introduced the term "response time" and how "lead time" comprises the response time. Response time is the time the competitors use to understand the new opportunity and develop a similar product. Lead time includes the response time, and the extra time from the benefits of patents, trade secrets or "*other means such as adopting pricing strategies designed to forestall imitation*". Sometimes there is a natural lead time advantage. Bjørnstad (2016) writing about plant breeders' rights,[3] points to new plant varieties having a biological lead time advantage of around ten years, where it is hard for competing breeders to create a similar variety. Plant breeders' rights then work by extending that natural lead time. Gómez-Villanueva and Ramírez-Solís (2013) reviews the literature on lead time advantages and show that there are industry differences. Also, they find, there is a first-mover *dis*advantage for consumer goods in mature industries. For consumer goods with high sales, they find a first mover advantage[4].

As discussed above, trade secrets are crucial parts in the composition of "lead time advantages", both conceptually and for practical management. As lead time advantage has no legal definition, it cannot be the object of a license, but trade secrets can. Thus, the knowledge that implies a lead time advantage may only be licensed in the form of trade secrets or other intellectual property. We have now presented how lead time advantage is an ambiguous term and a composite appropriation mechanism. When we consider how Cohen, Nelson, and Walsh (2000) and Hurmelinna-Laukkanen and Puumalainen (2007) see appropriation mechanisms as strategies and as interacting mechanisms without clear boundaries, we may view lead time advantages more as a strategy involving the flexible use of a collection of interacting mechanisms with the understanding that appropriation may not be permanent.

2.3 Appropriation Mechanisms

Appropriability, the possibility for governance, is a core concept in innovation research. Sun and Zhai (2018) show the evolution of appropriability research between 1986 and 2016. They find three areas where the debate is now: Platform governance, generative appropriability and how to select mechanisms that connect to business strategy. From that, they present a basic framework for appropriability research. In

[3] Plant breeder's rights is a type of intellectual property similar to and overlapping with patens. There is an international convention under The International Union for the Protection of New Varieties of Plants (UPOV).

[4] There is even a rule of thumb: The relative market share for the imitators is one divided by the square root of the order of entry.

this framework, the operation of the appropriation mechanism includes how it affects the firm's strategic decisions. The design of the mechanism and the operation is a separate field of research from the essential attributes of appropriation. These attributes include threshold and duality effects. The threshold is the fundamental attribute of changing the ownership and control of the technology. This attribute was central as the concepts of appropriability of innovation" and "appropriation mechanisms" developed in the late 50ies and early 60ies, for example, in (Arrow 1962). The background is referred to and discussed by Von Hippel (1982, 95,107). He lists three mechanisms for appropriation: patents, trade secrets, and response time - a part of the "lead time" concept we discuss below.

In the framework from Sun and Zhai (2018 fig. 9) the other essential attribute that the later literature study is "dual face". This term explains how appropriation has two effects working together: control and dissemination. As an example, De Rassenfosse, Palangkaraya, and Webster (2016) discuss this duality for patented technology when traded. Ownership influences the outcome of the negotiations, compared to the disclosure of the technology. Details of the technology are published through the patent system. That a patent discloses the technology makes the contract more complete. The duality is also there for trade secrets. The obvious use of a secret is to keep ownership and control. However, firms use trade secrets in knowledge exchange, that is dissemination. The duality can be observed on a macro level, where there is a positive association between the stringency of trade secrets protection and key indicators of innovation and international economic flows, implying knowledge exchange (OECD 2015a; Lippoldt and Schultz 2014). On a firm level, secrecy is a part of their organisational communication, internally and with other organisations (Hilgartner 2012; Fan, Costas, and Grey 2017; Costas and Grey 2014).

Researchers describe a multitude of appropriation mechanisms (Lopez 2009, 20-21). Teece (1986, 287 Fig. 3) discusses regimes of appropriability with two essential dimensions: The nature of the technology (product, process, tacit, codified) and the legal instruments (patents, copyrights, trade secrets). Lead time is only mentioned as part of how the innovator and imitator will position themselves. In Cohen, Nelson, and Walsh (2000, 8) there are not five or six distinctive *mechanisms*, but three *strategies* that can be combined: Complementary capabilities and lead time, legal mechanisms (notably patents) and secrecy. Lead time, secrecy and patents are seen as effective mechanisms for product innovations. For process innovations secrecy is the dominant mechanism (Cohen, Nelson, and Walsh 2000 figures 1-4; Arundel 2001, 621-622 fig. 1). The ranking is consistent with that by Eurostat (2016). Secrecy is here established as a more efficient or important way of appropriation than patents, copyright and trademarks.

In the early literature cited above, secrecy being a part of other mechanisms is not well explained, such as patenting being combined with secrecy. The point from Cohen, Nelson, and Walsh (2000) that there are not separate mechanisms, but rather strategies, is further explored by Hurmelinna-Laukkanen and Puumalainen (2007, 107). They link empirical data with a model for appropriability strategy and conclude that "*drawing lines between different appropriability mechanisms is challenging, because they interact and could be classified in many different ways*". Firms in most industries will use a multitude of appropriation mechanisms for the same invention. Patents complement secrecy, and copyright and trademarks are "far more widely used" (B. Hall et al. 2014, 419).

The Oslo Manual (OECD/Eurostat 2018, 113-115) has a normative list of appropriation mechanisms that are used in research and for statistics such as the Community Innovation Studies. The selection and division of appropriation mechanisms have evolved for each edition. These amendments demonstrate a point that Sun and Zhai (2018, 226) make: The research field and the terms evolve. There are now many new concepts discussed as appropriation mechanisms. A list is in APPENDIX A of composite mechanisms that to some degree include trade secrets or lead time advantages.

Now, with this as a background, before we turn to our study concerning collaborative research, we need to look closer at trade secrets and academic secrets for use in an early stage of innovation. In a framework for university-industry collaboration, our paper concerns the Formation Phase (Ankrah and Al-Tabbaa 2015 Fig. 1). For a complete innovation process, we study the very beginning, where it may be more relevant to discuss and measure the impact of university-industry collaboration at large, rather than appropriability (Perkmann, Neely, and Walsh 2011; Perkmann et al. 2013). However, if an innovation is to be appropriated by trade secrets that we explain now, the managers must decide this at the earliest phases of innovation.

2.4 *Trade secrets explained*

In legal terminology, information that is kept confidential to preserve competitive gains is referred to as “trade secrets”, “undisclosed information”, “business confidential information” or “secret know-how”. Business and academia sometimes use other name tags for it, such as “proprietary know-how” or “proprietary technology” (European Commission 2013a, 2). Most legal definitions of a trade secret include four concepts:

i) it is business-related technical or commercial information

ii) it must not be known to the public

iii) it must have value for business from being kept as a secret, and

iv) there must be a reasonable effort to protect the trade secret from disclosure.

Patent applications are usually kept secret for 18 months. During this period the applicant can consider if secrecy or a possible patent will serve them better.[5] Trade secrets are often compared to patents as an alternative for appropriating product, service or process innovations(S.J. Graham 2004; EUIPO 2017).[6] Most of the literature discuss trade secrets given these two innovations types, but the use of trade secrets is evident also in marketing innovations (D. Hannah et al. 2014; David R. Hannah,

[5] The management decision is complex, as there is no certainty in a patent being granted. Both secrecy and publication are alternatives that may function as appropriation mechanism, see (Holgersson and Wallin 2017)

[6] The definition of innovation types is from chapter 3.3. of the Oslo Manual, see (OECD/Eurostat 2018 Ch. 3.3)

McCarthy, and Kietzmann 2015) and for organisational innovations (Liebeskind 1997; Costas and Grey 2016).

The innovative firm manages secrets, for example, by using "Non-Disclosure Agreements" and defined work procedures. However, there are risks from misappropriation, such as cyber-criminality and employees leaving and then revealing the secrets to a new employer (David Hannah 2005; Robertson, Hannah, and Lautsch 2015). Like other forms of intellectual property, trade secrets can be sold and licensed. They can be a part of licensing in open innovation and other trade arrangements. This aspect of commerce and innovation is where the USA and EU now will be excelling: Their new, harmonised legislation on trade secrets, facilitates the improved exchange of knowledge in the form of trade secrets. There is an EU directive on trade secrets (European Commission 2016). The Congress of the United States of America (2016) passed the Defend Trade Secrets Act that allows federal courts to handle trade secret misappropriation. These laws together with international trade agreements, build an evolving legal framework for trade secrets. Other countries' legislation evolves too, but the harmonised laws in the EU and the USA will give more assurance and trust among firms and facilitate cross-border knowledge exchange (Caenegem 2014 §9.05). However, the legal framework may not be pivotal to the extent organisations use trade secrets, but rather the institutional environment and informal aspects (Delerue and Lejeune 2011).

2.5 Academic secrets

Trade secrets are per their definition above secrets that are business-related. In a collaborative innovation process, that includes university and industry partners, a secret research result may be of both commercial and academic interest. Academics keep secrets as a normal part of the research process and secrecy is an embedded process in all organisations (Bok 1982; Costas and Grey 2014). Thus, when considering collaborative innovation that involves academic institutions, there is a need for understanding academic secrets, that is secrets controlled by academics that may become or that at the same time are trade secrets. A typical example is the computer programme source code used in research, where the university usually will have the copyright. If the code is published, for example as open-source code, before the possible ways of utilisation have been considered, the research method and results may be disclosed too early. Both scientific publishing and future options for commercialisation may be lost.

Biagioli (2012) discusses "secrecy, openness and priority in science". His point is that secrecy within academia is risk aversion related to claims of priority. Scientists must publish to establish priority, that they were the first behind the new knowledge. By keeping their research secret, they reduce the risk of others publishing before them. The risk reduction applies to all systems of priority, including the system of scientific peer-reviewed journals, publishing in open depositories and patenting. Thus, the conflict between openness and secrecy may not always be between the norms of academia and the objectives of the industry. Instead, the conflict could be between the academic norms of openness and the academic objectives of publishing results. Gulbrandsen and Smeby (2005, 936, 946) expand this conflict in what they call the "secrecy problem": There are more collaborations, more publications and more entrepreneurial results from professors with industrial funding. Czarnitzki, Grimpe, and Toole (2015a) find in their study of German scientists that industry sponsorship of research, reduces the public disclosure of the results. Thus, it seems that possible requirements for secrecy from industry does not lead to less academic publishing, but perhaps more selective publishing.

Hong and Walsh (2009) explore the tension over secrecy between academia and industry. The study shows that there is a secrecy increase in science for the last 30 years. The increase holds for most industries. They underline that there is a complicated entrepreneurial relationship between industry and academia. Indeed, the broad literature review of academic engagement in commercialisation by Perkmann et al. (2013) shows that there is no conclusive evidence that industry exposure for researchers leads to increased secrecy and less academic publications. From this, literature then opens for a joint industry-university revealing strategy: There are tensions, but no presupposition that secrecy is needed forever, and as Resnik (2006) points out, secrecy is not un-ethical. A joint, revealing strategy is almost automatically in place if the collaboration parties agree on patenting for the appropriation of the innovation. The patent application is secret for a period, but the patent is not endangered by a scientific publication. However, if trade secrets are needed to appropriate the innovation, a publication of the trade secret will endanger the appropriation. This overview leads us to a summary of our framing that includes both academic and trade secrecy as well as lead time advantages.

2.6 *Model of our framing including renegotiation*

Somehow, in a collaborative innovation project between universities and industry parties, the parties must agree on the appropriation strategy. The university partners may have knowledge in the form of academic secrets, or if the commercial potential is clear, as trade secrets combined with patent applications. They balance the benefits of openness and secrecy into their own, preferred revealing strategy. The industry partners do the same: They consider the knowledge they bring into the project and the potential for appropriation and commercial utilisation with the resulting revealing strategy. If trade secrets may be needed, the management decisions must be taken as early as possible, to avoid loss of the secret. Therefore, in a collaborative innovation process, trade secrets must be managed also during research and jointly with the university partners. This management has a formal side that we explore in the empirical study of the contracts from collaborative research projects. Nevertheless, there is also an informal side with group processes and trust as moderating factors. Olaisen and Revang (2017) discuss how there is an interaction between trust and the use of intellectual property. They find that trust in collaborative project teams increases with clearly defined contracts and intellectual property rights. The collaboration agreements can be viewed as incomplete contracts, that is the parties do not know the outcome, as research results are by nature uncertain. Thus, the initially negotiated distribution of ownership and use rights to the research results should be re-negotiated when the outcome is better understood. Also, the parties will at the same time try to reduce the transaction costs (Aghion and Tirole 1994; Hart and Moore 1988; Rosenkranz and Schmitz 2003). Contract templates reduce transaction cost, and thus the public sponsors, as well as research organisations, provide normative templates for research consortia. These templates have predefined clauses on confidentiality and publication, that may be modified (DESCA 2017; The Research Council of Norway 2019).

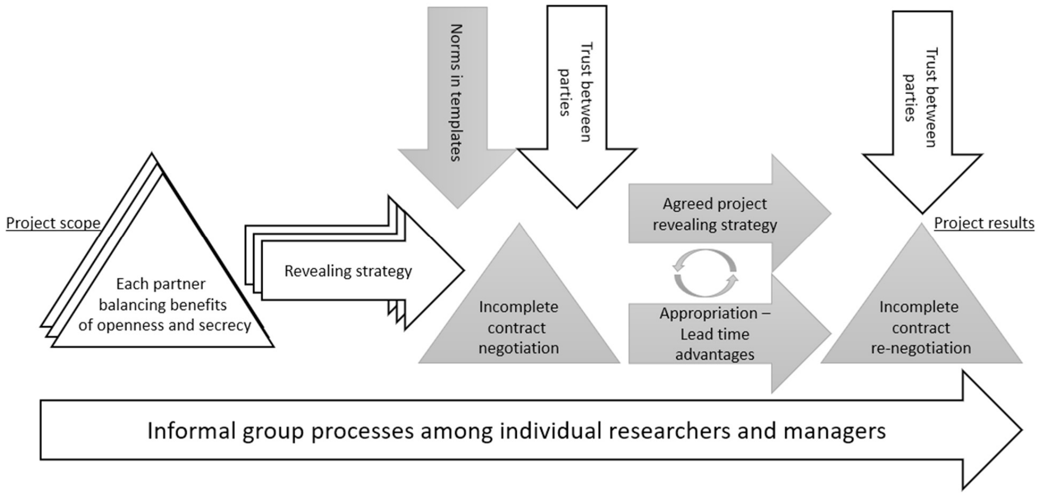

Figure 3 A framework for revealing strategies and incomplete contract re-negotiation. The shaded figures are the parts discussed later in this paper.

In Figure 3, we show a framework for our empirical study building on the above-cited literature. Each party to the collaboration comes with their background knowledge within the project scope and balances the benefits of openness and secrecy (Contractor 2019). Each party has a preferred revealing strategy (Alexy, George, and Salter 2013). They negotiate, and the templates and existing trust modifies the negotiation, as well as informal group processes (Alcover et al. 2017). If the parties are used to working together and have a high level of trust, the contracts can be less detailed, or more easily defer problematic issues to a later stage or a steering group.

The outcome of the negotiation is an agreed revealing strategy for the project and an agreed strategy for appropriation. As we have presented above, an agreement on lead time advantages will include agreements on secrecy and publication. As the project ends and the results are understood better, the ownership and use rights to the results can be re-negotiated (Rosenkranz and Schmitz 2003; Granstrand and Holgersson 2014). We now turn to the empirical part of the paper, where our data is the contracts resulting from the middle triangle in Figure 3.

3 Empirical study

3.1 Data, samples and tools

We used a set of contracts from 483 collaborative research projects. All were funded by the Research Council of Norway (RCN) between 2008 and 2017. We initially made a random selection of 1000 projects from a total of 21838 in that period. The selected projects had at least one university and one industry partner and belonged to a technology research programme. We then dismissed projects that were not collaborative or where appropriability and innovation were not issues, such as support to conferences. Recommended by the RCN, the Norwegian Ministry of Education and Research permitted us to study the agreements between the parties in the projects.[7] The RCN archives not only the sponsor contract between the project coordinator and the RCN but also the agreements between the parties. These agreements must follow RCN's permissive policy on intellectual property, but the negotiations are not monitored or checked by the RCN. Thus, the parties freely negotiate their agreements. There are templates available, but they are not mandatory (The Research Council of Norway 2008, 2019). Many agreements could not be retrieved from the RCN's data-based archive for unknown reasons. Others were impossible to read due to scanning errors or had missing parts. We found no systematic errors and decided to use only the

[7] Norwegian law allows researchers access to such material under strict confidentiality and special terms from the Ministry. The terms guarantee the anonymity of the study objects. Thus, we could not contact the projects to verify or discuss information in the contracts.

readable, complete agreements. We then had 3937 agreements from 483 projects. We checked that the projects with non-retrievable agreements had similar characteristics with the retrieved ones, in terms of budget, number of partners and field of technology. We concluded that our set is representative.

The agreements were all scanned pdf-documents, as images and not with characters embedded. We read all and recorded our scores and comments in Excel. After our initial analysis and our surprise, we transferred a subset, discussed below, to a Nvivo 12 database for qualitative analysis. We then re-coded these projects with additional data.

3.2 *Attributes, measures, coding and re-coding*

For each of the 483 projects, we recorded publicly available data, such as the start and end dates, the number and types of partners, the budget, the public funding and the project coordinator. In addition to the publicly available data on each project, we also recorded, as we read the agreements, if they were bilateral or consortium agreements, and if an RCN template was used.

There are in average eight parties per project, with a minimum of two and a maximum of forty. The balance is good between academic institutions and industry. Around 30 per cent of the parties are universities, around 15 per cent are research institutes. The average budget of the projects is 3 million euro, with a minimum of 20 thousand euro and a maximum of 43 million euro. The average degree of public funding is around 60 per cent, with a minimum of 8.5 per cent and a maximum of 100 per cent. A major part, 35 per cent of the projects we studied are defined as “innovation projects”, that is more applied research. Around 33 per cent are “competence building” projects where the primary purpose is to create knowledge of skills that are useful for innovation, education or further research. The rest of the projects we studied include basic research, special projects or PhD-programmes. We had the RCN’s classification, and we then aggregated these into tags for innovation, competence building and other projects.

We reviewed the description of each project together with the research programme it belonged to. Based on that we coded each project's field of technology to be one of: BIO (all life sciences), ENERGY (petroleum, wind, solar, hydro-electricity), ENGINEERING (mechanics, material sciences, manufacturing), ICT (information technology, communication technology, artificial intelligence), OCEAN (aquaculture, shipping, non-energy, generic subsea), OTHERS (such as ecosystems, climate research and transport systems).

We then scored and coded each project on Confidentiality and Publication. Confidentiality is the right that parties to the research collaboration agreement have in requiring confidentiality on the research results or project background from the other parties. Publication is the right each party has, to publish the research results or project background from the other parties. We read the contractual clauses and scored each project according to Table .

Publication	**Confidentiality**	**Score**
All dissemination of project results is strictly controlled. No publications allowed	All information is by default confidential if not already public. No specified timeframe or other limitations	**1** **Restricted knowledge flow**
Project results must be published but could be delayed according to participants needs. Not specified publication for academics	All project results and background information disclosed are by default confidential if not already public, limited in time	**2**
Results shall be published, but publication must be sent to Steering committee which could object and request modifications before publication	Project results and background information are confidential if marked, justified and limited in scope and time	**3**
Publications could be delayed due to patent or other justified grounds, but according to national laws. Must be clearly stated that results must be published within a time frame	Project partners have to specifically request confidentiality. Information must be marked confidential, time-	**4**

	limited and approved by the steering committee. Parties could refuse	
No publication restriction. Specified that results must be published	No terms on confidentiality specified	**5 Open knowledge flow**

Table 1 Scoring - the score "1" used to select the subset is marked

We based the scoring table on typical contractual clauses in the agreements and from templates such as DESCA and the Lambert toolkit (Eggington, Osborn, and Kaplan 2013; DESCA 2017). A score of 3 indicates a score where there is a balance between the rights to publish and the right to keep the background and the results as trade secrets. The steering committee of the project has a role in overseeing that planned publications do not interfere with the planned use of appropriation mechanisms, such as patents. With a score of 3, a trade secret is limited in time. With a score of 1, all results and background can be kept as trade secrets forever with no requirements for publication. RCN's policy document requires that research results are published. The clauses in the agreements, however, give one or more parties control over what is to be published. In this way, overall results may be published, whereas the workings or critical details may be left out. With a score of 5, there are no requirements for confidentiality, not even for the background knowledge that the parties bring into the project when it starts. All results can and will be published. Publication hinders the use of trade secrets as an appropriation mechanism, as the legal criteria of efforts to protect the trade secrets from disclosure is not in place. Lead time advantage that includes those trade secrets will then be limited to the response time, the time it takes for others to read the results and act on them.[8]

[8] Acting on the revealed knowledge can be difficult for a competitor. In the «Profiting from Innovation» framework there is not only the appropriability regime, but also «complementary assets» that explain what must be in place for profitability. As it takes time to get complementary assets in place, this could be included in the lead time concept, but has not been so in the innovation literature. See (Teece 1986).

The authors scored the projects in the period 2017-2018. We scored the first 30 projects separately and then compared the results, clarified the wording in the scoring table and divided the rest of the work. For the few differences, we shared the scoring and discussed cases of doubt between us. As we analysed and discussed our data, we realised that there were very few agreements with clauses on possible appropriation by trade secrets or lead time advantage. Motivated by curiosity we then created a subset of the 483 projects where either the Confidentiality or Publication was "1 - Restricted knowledge flow". We reasoned that these projects are the ones where trade secrets could be the appropriation mechanism and where lead time advantage could be used. We added to the set projects where we found contractual clauses that in clear text specified that results could be trade secrets (or similar terms).

Our subset has 52 projects. We then studied the agreements in detail for each of these projects. We looked at the balance between publication and confidentiality, and for other related clauses. We decided on how to re-code the subset, and we added the relevant tags in Table 2 for each project. As the tags are objectively defined, there were no cases of doubts during the re-coding.

Tag	**Description**
Background forever	The background information the parties bring into the project can be kept as a trade secret forever.
Background medium	The background information the parties bring into the project can be kept as a trade secret for a limited number of years, such as five years.
Inconsistent	The clauses on publication and confidentiality are inconsistent. For example, could publication of all results be required within one year, but the industry partner could require results to be trade secrets indefinitely.

National security	The secrecy requirements are not for the appropriation of the innovation but due to military requirements or the security of national infrastructures, such as the power grid.
PhD	The requirements for publication are connected to the results being part of a PhD-thesis.
Results forever	The research results can be kept as a trade secret forever.
Results medium to long	The research results can be kept as a trade secret for three to ten years.
Results short	The research results can be kept as a trade secret for half a year to two years. This period is typically used for trade secrets that will be part of a patent application.
Results unclear	There are some provisions for keeping the research results secret, but no definite time or mechanism is defined.
Trade secrets or secrecy	The use of trade secrets as an appropriation mechanism is explicitly anticipated in the agreement.
University clause	The university refers to the publishing of the results being a legal requirement that they can only dispense from for half a year to one year.

Table 2 Coding for the subset of 52 projects

3.3 Empirical results

Initially, we note that the subset with restricted knowledge flow is around 11 per cent of the total number of projects we reviewed. We have categorical data and use cross-tabulation. First, we look at the distribution between fields of technology in Table 3.

Technology Area	**Count all N=483**	**Count selection N=52**
BIO	24%	15%
ENERGY	32%	44%
ENGINEERING	3%	6%
ICT	10%	8%
OCEAN	16%	15%
OTHERS	15%	12%
	100%	**100%**

Table 3 Counts of Technology Areas

The distribution of the selection has a similar shape as the distribution for the complete set. We see that the energy field is overrepresented, and the biotechnology field is lower. We find that 58 per cent of the agreements are based on RCN's templates; in the selection, 52 per cent use the RCN templates. We did not record the use of other templates such as DESCA.

We note that there are few projects in each technology field, with 23 in energy and only three in the engineering field. We then turn to the coding we did for the projects in the subset, inTable 4.

Projects	ENERGY	OTHERS	OCEAN	BIO	ENGINE-ERING	ICT	Total (52)
Background forever	19	5	5	5	3	3	40
Background medium	3	1	2	1	0	0	7
Inconsistent	2	1	2	1	1	0	7
National security	1	0	0	0	0	0	1
PhD	1	0	1	0	0	0	2
Results forever	5	0	3	3	3	2	16
Results medium to long	7	4	2	4	0	0	17
Results short	8	1	3	1	0	0	13
Results unclear	1	1	0	0	0	1	3
Trade secrets or secrecy	5	0	0	1	2	3	11
University clause	8	4	1	0	2	3	18
Total (unique)	23	6	8	8	3	4	52

Table 4 Cross-tabulation of project coding and technology areas. The number of projects is in brackets.

“Others” has too few projects for commenting and is diverse. In the engineering field, two out of the three projects are projects we tagged for being explicit on trade secrets and for all the projects the results and background can be kept secret forever. One of the agreements is inconsistent, meaning that it allows for eternal secrecy and gives the university the right to publish.

The energy field has a higher share of projects with background knowledge that can be kept secret forever. In this field more of the agreements allow for keeping the results secret, but there are differences in the time they can be kept. The ocean and bio sectors are similar. There are differences in the time results can be kept secrets. For some projects, the background can be disclosed. There are only four ICT projects in the subset. In three of these, there were explicit contractual clauses on trade secrets, combined with a clause where a university partner says results must be published. We still consider that these trade projects can use trade secrets, and thus keep a lead time advantage. Below we discuss this combination of secrecy and publication requirements, that we do not consider inconsistent.

We then turn to the cross-tabulation for the two types of projects “innovation” and “competence” in Table 5.

Projects	Competence	Innovation	Other	**Total (52)**
Background forever	15	21	4	40
Background medium	2	5	0	7
Inconsistent	3	3	1	7
National security	0	1	0	1
PhD	0	1	1	2
Results forever	4	10	2	16
Results medium to long	6	10	1	17
Results short	6	6	1	13
Results unclear	1	2	0	3
Trade secrets or secrecy	3	6	2	11
University clause	7	8	3	18
Total (unique)	18	29	5	52

Table 5 Cross-tabulation of project coding and project types. The number of projects is in brackets.

There is a clear difference between the competence and the innovation projects: A higher share of the innovation projects can keep the background and results secret. The “result short” coding has the same share, pointing to patenting being possible to the same extent. Explicit clauses on trade secrets are more prominent among innovation projects. Table 5 indicates, as expected, that there is more use of secrecy in the applied science projects, here termed as “innovation projects”.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1 : Background forever	40										
2 : Background medium	0	7									
3 : Inconsistent	3	0	7								
4 : National security	1	0	0	1							
5 : PhD	0	0	0	0	2						
6 : Results forever	11	0	1	0	0	16					
7 : Results medium to long	15	0	0	0	0	0	17				
8 : Results short	6	2	0	0	0	0	0	13			
9 : Results unclear	2	0	0	0	0	0	0	0	3		
10 : Trade secrets or secrecy	7	0	0	0	0	0	1	0	0	11	
11 : University clause	15	0	1	0	0	1	0	0	0	0	18

Table 6 Cross-tabulation of the tags

In Table 6 we cross-tabulated the tags. Here we note that for projects that have agreed on the background being secret forever, there is a high number of projects where the results can be kept secret forever or for a longer time than needed for patenting purposes. There is also a high number of “university clauses” for these projects and a few inconsistencies, where publication is agreed even if the results are to be secret. We assume that the background secrets are not academic but belong to the industry partners. We saw examples of that in the agreement annexes that define the background. We never saw academic secrets mentioned there, but we have not verified it by re-reading all agreements. As there is a time lag between the background and the results, for the projects that have secrecy included for both, we assume a causal relationship where the background secret will be needed to implement the possible results.

We base our hypothesis development on the tabulations of the raw data above and the discussion that follows next.

4 Discussion leading to hypotheses

4.1 Selecting appropriation mechanisms in an early stage of collaborative research

We started our paper by sharing our surprise when we found that only 52 out of 483 collaborative research projects had contractual clauses that allowed for trade secrets as an appropriation mechanism. Most of the 483 projects have provisions that allow patenting. The Norwegian law on employees' inventions, similar to most other countries, gives the employer, including universities, the right to apply for a patent (Wolk and Szkalej 2016). Thus, the contract templates used during negotiations between the project parties cater for this. Universities should prefer patenting to trade secrets, as patents are published. The patented knowledge may then freely be used in education and further research. Typical contractual terms will be that planned publications that may hinder patent applications by making them obvious can be delayed for some months. This delay allows for drafting and filing a patent application. The 13 projects we coded with "results short" have such provisions, but so have most of the 483 projects, either from the agreements or Norwegian background law.

"Lead time advantage" may comprise patents and patent applications. A published patent application is a risk for competitors. If the patent is ever granted, the claims can be valid retroactively, from the publication of the application. Patenting thus provides a lead time advantage when the application is published and is well suited for research collaborations: The research results are published; appropriation is possible if the patent is granted.

Patent prosecution can take a long time, as can innovation beginning with a research project. The possibility of building a portfolio of appropriation mechanisms is then a part of the project management. There is an empirically based overview by Henttonen, Hurmelinna-Laukkanen, and Ritala (2016 table 4) of mechanisms for appropriability in connection with R&D collaborations. Here secrecy and lead time are not noticeable mechanisms in collaboration between firms and publicly funded research organisations, whereas patents are. However, secrecy is important in the firms' R&D collaboration with suppliers. In our study, we lack this distinction: In the collaborative research projects we studied, there may be both suppliers and users of technology together with universities and research institutes.

Petrusson (2016, 344-346) points to how trade secrets are problematic for universities. The context is that the universities must take responsibility for the utilisation of the research. Trade secrets are then one of the possible methods to control how the new knowledge is transferred between the parties in the collaborations. For example, in Table 4 we see that three of the four ICT projects in our selection use trade secrets. Two of them allow for eternal secrecy of the results in addition to the background. Typically, the appropriation mechanisms for software that is not open source is copyright in combination with keeping the source code secret. This combination reflects the business models in the software industry. Petrusson (2016) discusses how an academic institution can promote utilisation in different ways, or logics – similar to overall business models. A prerequisite is that the knowledge assets can be identified, described and is possible to transfer. Thus, intellectual property is needed if the academic institution wishes to be in control. None of the 52 collaboration agreements we studied in detail, or the templates that we have reviewed, connect a planned utilisation with the choice of appropriation mechanisms. The agreements are not clear on the scope of possible utilisation; the logic to be used for utilisation of the research results is not identified. The contractual clauses are consequently not adapted to the appropriability logic. That is, we can observe an agreed possible delay of publication, that requires justification, but the clauses are not connected to how the project foresees governance of the research results. In other words, there is rarely a revealing strategy behind the clauses. Here we add to the selective revealing discussed by Alexy, George, and Salter (2013) that concerns firms only: The revealing strategy in a collaborative project, is the result of the negotiations between the parties and should be documented in the collaboration agreement, as we show in Table 4 and Table 5.

H. Stevens et al. (2016) divide early-phase public-private research partnerships into three types: Partnership focused, Hybrid and Open Collaboration. They show how these differ in terms of variations in intellectual property rights to background and results, in the same way as we have in our Table 4 and Table 5. They conclude that there is no single intellectual property framework that applies to every partnership in early-phase research. From Table 5 we show a difference between innovation (applied research) and competence projects (basic research). The templates that the RCN provides for these project types are the same, even if their scope – competence building or innovation – differs. There is then a possible mismatch between the templates and the needed intellectual property framework, but a likely reduction of transaction costs.

From this, we hypothesise for future and broader studies that:

> *Hypothesis 1: Few university-industry research collaboration agreements will have clauses that enable mixes of trade secrets and other appropriation mechanisms. The mix will vary with the field of technology, and if the research is basic or applied.*
>
> *Hypothesis 2: University-industry research collaborations agreements that allow secrecy as an appropriation mechanism, will document the revealing strategy as possible delays in publication.*

In all the projects in our study, one or more universities participate. On the one hand, we were surprised to find so few projects with trade secrets as an agreed appropriation mechanism. On the other hand, we should be just as surprised that we found anyone at all, considering the universities normative resistance to secrecy that we discuss next.

4.2 *Academic norms*

Perkmann et al. (2013, 433) discuss how academic science is diverse, and the Mertonian norms, for our discussion, the norm of "communism" cannot apply to all institutions. Merton (1973, 273-275) calls secrecy the antithesis of science. Perkmann et al. conclude that *"An important objective for future research is … to question the pervasiveness and purity of the Mertonian norms, and shed light on the … diverse patterns of university-society interactions …"*.

Mukherjee and Stern (2009) present an economic model for the balance between secrecy and open science, indicating that open science creates more social welfare. However, open science is not always possible, and if not, secrecy may have benefits. This balancing is not recognised by universities in our study. In Table 4 and Table 5, around 40 per cent of the projects in our subset still have a clause that says the universities due to legal requirements *must* publish. In most of the agreements, this duality is left unsolved. In a few contracts, the conflict jumps out of the text, as shown in Figure 4.

The Consortium participants, however, understand and acknowledge that according to the NTNU Committee resolution (S-sak 10/09), any request for postponement of publication of Project results, in which NTNU employees have contributed fully or partially to generate, shall be considered by the Rector of NTNU. The Rector of NTNU may consent to postponement of publication for up to 6 months, with an option for further 6 months when there are legitimate reasons for this. The maximum limit of 12 months' is not to be used as a standard procedure. In any event, publication shall take place as soon as possible.

For prosjektresultater frembrakt av ansatte ved Samarbeidsparten, vil universitets- og høyskoleloven gi begrensninger vedrørende utsettelse av publisering. Styret ved institusjonen (eller den som har fått delegert avgjørelsesmyndighet) kan samtykke til utsatt offentliggjøring når legitime hensyn tilsier det. Det kan ikke avtales eller fastsettes varige begrensninger i retten til å offentliggjøre resultater utover det som følger av lov eller i medhold av lov. Offentliggjøring kan ikke skje dersom det vil avsløre bedriftshemmeligheter.

Figure 4 "University clauses" from two of the agreements in our study. The underlined text says trade secrets will trump any requirements for publication. (Translation of the Norwegian part is in the article).

In the first example, there is a cut-and-paste clause where the university partner refers to a decision by their board. The university rector may consent to a publication delay up to 12 months. The industry partners accepted this. In the second example clause the translation of the pertinent parts from Norwegian is: *For project results produced by the employees of the University, the law sets limitations for any delay in publication. The board of the University may agree to delayed publication for legitimate reasons. No permanent limitations are allowed on the right to publication, except what follows from or is in accordance with law. Publication may not take place if it would reveal trade secrets.* The underlined sentence is added to the cut-and-paste clause, probably by an industrial partner.[9] The sentence before shows the inherent conflict between two sets of law: Publication must take place, because the university law says so, but only if there is no other law saying otherwise.[10] We do not think it is wise to enforce secrecy upon unwilling university researchers when the industry partners figure out that appropriability can only be ensured by trade secrets. The universities generally lack the support systems needed to keep trade secrets. Thus, the contractual responsibility would rest on the shoulders of the individual researcher. That is neither reasonable nor fair. However, from Table 6 we noted that when the results are to be held secret, mostly there is a secret background as well. Then, the universities must have systems in place to handle secret background information, if they are to participate in these projects. From this discussion, we hypothesise for further studies that:

9. We speculate, but there is no reason why the university partners should add the underlined text to their own cut-and-paste text on publication, that we noticed in many agreements.

10 In Norway, those other laws include the provisions in the marketing law and the penalty code on trade secrets. In other words, Norwegian jurisprudence support that trade secrets can trump requirements for publication, like privacy law and national security, but it is not clear what the requirements are, for example results being jointly owned, see page 54-55 in (Irgens-Jensen 2010, 54-55)

Hypothesis 3: A substantial number of university-industry research collaboration agreements where secrecy is agreed for the background, will have trade secrets as a possible appropriation mechanism for the results and may have contradictory university-initiated clauses that limit permanent secrecy.

This tension, resulting from a perceived dichotomy of openness versus confidentiality leads to the next discussion.

4.3 *Management of lead time advantages as a frame for renegotiations*

Finally, we address lead time advantage and renegotiations. Aghion and Tirole (1994, 1192,1201) propose that ownership is determined by the underinvestment by both parties and ex-ante bargaining power. They further propose that ownership should be split between the parties according to comparative advantage in creating value. The ownership of the research results is controlled with appropriation mechanisms. Lerner and Merges (1998) explore this further in an empirical study of alliances between biotechnology firms. The critical role that "control rights", that is governance, have in commercialisation points to our discussion on how possible trade secrets and lead time advantages are managed. Rosenkranz and Schmitz (2003) introduce a model for allocation of ownership rights in dynamic collaborations building on the same ideas of incomplete contracts, but also with only two parties to the contract. There is more to learn from the contract and accounting literature on how multiple parties and public-private partnerships negotiate incomplete and collaborative contracts (Sarmento and Renneboog 2016; Krishnan, Miller, and Sedatole 2011).

This contract theory line of literature, however, does not discuss how appropriability is a prerequisite for ownership, as the mechanisms for ownership are known when these models are discussed. In our study, we are in an early phase of innovation, where the parties still have not concluded on appropriation, that is the form ownership will take. When we apply the perspective from the theory of incomplete contracts on the question of appropriation mechanisms, there are then these theoretical considerations for who ex-ante should be in control of the technology leading to that control should be renegotiated. We find that the incomplete contract theory brings a much-needed perspective on the collaboration agreements we study, and that it fits well with the concept of lead time advantage.

Lead Time Parameter	**Terms observed in empirical study**	**Background, from each party to the agreement**	**Results from the research project**
Trade secrets	Yes	Yes	Yes
Academic secrets	No, not explicitly	Yes	Possible, but not likely
Patents	Yes	Yes, both applications and granted patents	Usually patent applications due to the time to grant
Designs	No (but may be understood as part of "patenting")	Yes	Yes
Copyright and similar	Yes	Proprietary code and databases	Yes, including open source
Trademark	Yes	Yes	Yes
Publication	Yes	Yes, some research institutions list journal publications as background knowledge.	Yes, in the sense that it stops other from patenting. Yes, in the case of open source code.
Time	Yes	Yes, for secrecy or delay of publication	Yes, for secrecy, patenting or delay of publication

Table 7 Lead time parameters

In Table 7 we show likely parameters of the lead time advantage construct. The first column shows if we observed the terms in our empirical material. Academic secrets were never discussed explicitly in the agreements. However, a university partner could use the agreed terms on confidentiality and delayed publishing to keep an academic secret. Design registration may have been understood to be a part of patenting or copyright. In the columns for background and results, we comment on the applicability of this parameter. From this decomposition of lead time advantages and our observations in the material, we propose a new model.

In Figure 5, we show how the parties jointly decide on the available set of appropriation mechanisms. The figure is a variant of the right-hand part of Figure 3, where the renegotiation is now a contractually agreed activity, together with the revealing strategy. The parties to the contract first decide on the mix of appropriation mechanisms, that will create a lead time advantage, in agreement with the business model or utilisation logic of the project. This decision is then followed by the execution of the revealing strategy and renegotiations as needed. The difference from what B. Hall et al. (2014) and Henttonen, Hurmelinna-Laukkanen, and Ritala (2016) discuss is that we integrate the concepts of academic secrecy and publication. Thus, in this framing, the requirement for appropriation is not only a matter for the industrial part. Secrecy is here an opportunity for both university and industry partners. The publication is not opposed to industrial interests. The framing consistently applies the term “lead time advantage” building on the definitions found in the management research literature, and the duality of appropriation mechanisms that Sun and Zhai (2018) show is a key issue in recent research. Thus, in the model in Figure 5 we have substituted the university-industry dichotomous model of secrecy versus publication, with lead time advantages as a concept.

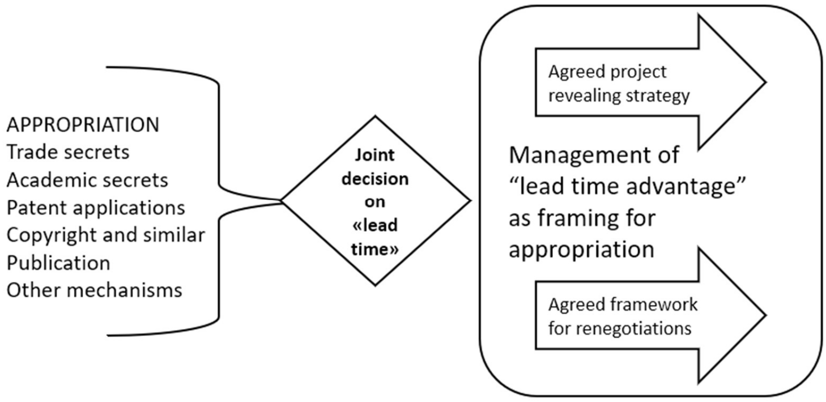

Figure 5 Management of lead time advantage as a framing

From the above we propose:

> *Proposition: The secrecy-publication dichotomy in university-industry agreements on collaborative research can be replaced with the management of lead time advantages including a revealing strategy and appropriation.*

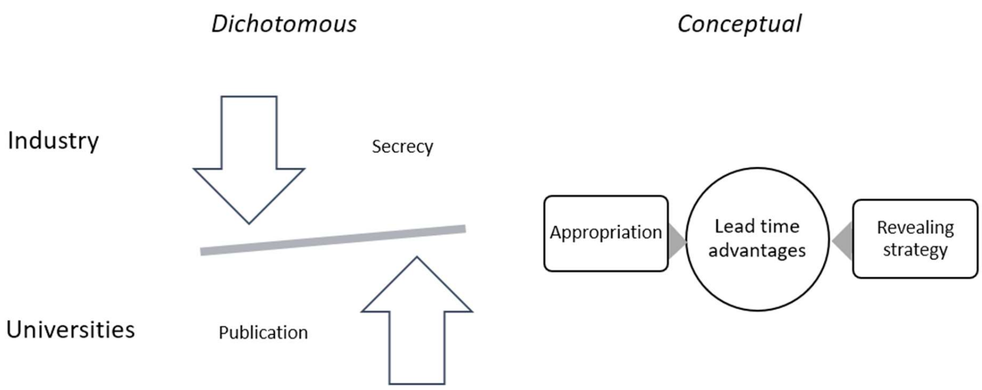

Figure 6 A dichotomous view versus using lead time advantages as a concept

Figure 6 illustrates our proposition for lead time advantages as a reframing of the secrecy-publication dichotomy. On the left hand is the current way of writing collaboration agreements, and thus, the literature reflects this dichotomy. The industry parties to a collaboration agreement require secrecy as an enabler of appropriation, both through trade secrets and patents. The universities require publication. We illustrated an inconsistent outcome by the "university clauses" in Figure 4. The intentions of the inconsistent clause could have been better framed as an agreement on lead time advantages. Accordingly, on the right hand is our proposition, where lead time advantage conceptually encompasses both the need for appropriation and the agreed revealing strategy. We consider renegotiations to be more accessible in this setting, as lead time advantages remain a broad concept, and the dual face of appropriation includes both control and dissemination. Further research that we discuss next may find that research collaborations can accept "management of lead time advantages" as a frame for their appropriation of innovation.

5 Directions for further research and conclusion

As secrets are rarely measured – the role they have in research impact is not well understood. One aspect is the role that trade secrets have in knowledge transfer, such as in licensing. The societal use of research results is broader than the commercial utilisation alone. Trade secrets' role is by its definition limited to trade and commerce. Then a simple view can be that if the user can only benefit from the research results if they are kept secret, then the research results should be managed as trade secrets by their "missed opportunity matrix" (Sarewitz and Pielke 2007, 12, fig. 1). In terms of research portfolios and how policy affects the choice between the projects, the need for secrecy and industrial collaboration should then not be a negative factor.

Our hypotheses can be tested by further analysis of collaboration agreements combined with interviews. In our study, there is a legal requirement that we do not contact any party. Thus, we lack qualitative data, aside from the contract terms. Interviews with project participants before and after the negotiations and at the end of the projects, together with an analysis of the contractual terms, is needed to understand if our proposition can be of use.

One major limitation of our study is that we have a sample of Norwegian collaborative research agreements. Norway is a small country within the EU-compatible European Economic Area and with contract law based on civil law. Also, our study builds on written contractual agreements only. Trust may be a modifying factor, and there is an interesting concept of psychological contracts in project teams that may complement the written contracts (Therese E. Sverdrup and Schei 2015). We look forward to comparable studies from other countries and to studies that include interviews that can tell more about the unwritten interaction between managers and research teams.

We have contributed to management science ontology with a clarification of the ambiguous term lead time advantage and how that concept relates to academic secrets, trade secrets and other innovation appropriation mechanisms. With our cross-tabulations, we empirically showed different aspects of the project agreements that restrict knowledge flow by trade secrets. We contribute to theory in that we connect the concept of incomplete contracts with the structure of the collaboration agreements, the appropriation mechanisms and the need for renegotiations. We extend the selective revealing from Alexy, George, and Salter (2013) to university-industry research collaborations. We propose that the management of lead time advantage is an acceptable framing for both university and industry partners in collaborative research.

Our research goal was to hypothesise how the incomplete contract parties foresee the use of and agree on trade secrets and lead time advantage. Given our proposition to use lead time advantages as framing for collaboration negotiations, we wish to initiate a discussion on how to implement new contractual regimes for university-industry collaborations that cater for a balance between secrecy and openness. This discussion concerns research and innovation managers, as well as policymakers, and should consider how the discussed framework on appropriability comprises both dissemination and control, working together.

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7 APPENDIX A

The examples of composite appropriation mechanisms below are not exhaustive. They relate to trade secrets or lead time advantage. Complexity is sometimes mentioned as a mechanism, for example in the Oslo Manual. Complexity is simply a composite variant of lead time advantage with trade secret: If a competitor can see the technology but cannot copy, there is either a secret in how it works, or a lack of resources to copy. As we study how the contracts use appropriation mechanisms, it is of interest that the contracts themselves can be regarded as such a mechanism:

- Human Resources Management (HRM): HRM comprises employment contracts, restrictions on employee mobility and communication. "Tacitness" interacts with "secrecy" and other appropriation mechanisms (Hurmelinna-Laukkanen and Puumalainen 2007).
  (Thomä and Zimmermann 2013) point to the complementarity observed between employee retention and lead time advantages. Long-term retention of employees is more important than lead time advantages and secrecy. Their findings are consistent with the earlier ones of (Blind et al. 2006).
- Labour legislation is in (Hurmelinna-Laukkanen and Puumalainen 2007) discussed as a mechanism. It is partly overlapping with HRM and includes employment contracts, employee non-competes and also legislation on employment inventions (Hurmelinna-Laukkanen and Puumalainen 2007, 97). The mobility of the workforce can be restricted by "non-compete clauses" in the employment agreements. Protecting trade secrets is often an important issue in such agreements, as is the balance with the employers right to whatever skills and knowledge they have acquired. "..mobility restriction mechanisms affect appropriability through their impact on secrecy and lead time" is a conclusion in (Delerue and Lejeune 2010).

- Contracts: are discussed by (B. Hall et al. 2014, 98-99), partly as an underlying mechanism for the management of secrecy. In a survey of 100 European firms, the literature on contracts as an appropriation mechanism is reviewed (Hagedoorn and Zobel 2015). Contractual appropriation mechanisms, in particular, given open innovation and utilisation of academic research is discussed in (Petrusson, Rosén, and Thornblad 2010) and in (Petrusson 2016, 345-347). Trade secrets are often regulated by contracts. The contract may, for example, define who has access to the secret under what terms and for how long the secret will be kept.
- Branding, marketing and advertising: (Y.K. Ho, Keh, and Ong 2005) connect advertising to marketing and branding, and then to how brand names build barriers for competitors (Y.K. Ho, Keh, and Ong 2005, 4). Branding relates to the even broader term "lead time advantages" and would then include the use of trademarks, or a composite of trademarks, copyright, designs and the reputation that patents give. Secrets contribute to branding and marketing (D. Hannah et al. 2014). Branding is the only way to license a first mover advantage.
- Publication, disclosure: Disclosure or publishing is a variant of the combinations of patenting and secrecy (S.J. Graham 2004; Holgersson and Wallin 2017). Publication or strategic disclosure of an invention will make it impossible for others to patent the same or a similar invention. Publication and disclosure then become part of a continuum with secrecy and "tacitness".
- Modularity, segmentation: Modularity can be used "... to disperse and hide information that might otherwise be difficult to protect through the legal system." (Baldwin and Henkel 2015). The mechanism is close to "complexity of design", though the point here is not complexity, but how technological and organisational modules can be used. (Gooris and Peeters 2016) build on this modularity: IT-enabled integration of business processes makes it possible to use modularity and avoid misappropriation. Writing from a legal point of view, (Villasenor 2015) uses the same argument and calls it "segmentation.

Modularity is used to keep trade secrets and reduce the risk of misappropriation.

- Certifications and standards: There are historical and current examples in (Jacobides, Knudsen, and Augier 2006, 1204). The guarantee for quality that is discussed is closely related to the primary function of trademarks. Patents and patent pools interact with technology standards, and this affects firms' appropriation of innovation (Vakili 2016; Heiden 2017, 19; Timo Fischer and Henkel 2013, 327).

Research paper 3:

Monopoly spotting: The management of openness in research collaborations between universities and industry

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Monopoly spotting: The management of openness in research collaborations between universities and industry

ABSTRACT

Industry and universities engage in collaborative research often without a clear understanding of how open the research results should be. The contractual terms of the research project document agreed on openness. The terms also decide if access through licensing will be exclusive to a few, or available for the many in open innovation. However, collaborative research agreements are complicated with entangled terms. We applied a novel method for analysing such agreements on 484 publicly sponsored projects in different industries. Placing the projects in the method's two-by-two matrix, we found that around 20 per cent of the projects, across all industries, have agreements that allow knowledge monopolies to form. We find a positive association between the openness of the research results and the projects that are climate and transport-related. For organisations, research managers and policymakers, the method can be used on a single project or a portfolio of collaborative projects to better align with research policy.

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1 Introduction

The Lund Declaration provides direction for the next European research framework programme: "*Public research organisations role in knowledge exploitation through open innovation and co-creation should be reinforced"* (Lund 2015). Such reinforcement requires an understanding of how the role is enforced in the first place. Schot and Steinmueller (2018) suggest that the needed transformation of research and innovation must comprise a new framing for innovation policy, "Framing 3". They point to directionality failures, saying "*Transformative innovation policy therefore faces difficult ex-ante and continuing trade-offs among the interests and visions of different groups*." However, the ex-ante trade-offs are not only political processes between interest groups but also negotiations between the public research organisations and industry.

Our study concerns the question of openness in publicly sponsored research results. We define openness as a continuum from no openness at all to full openness of research results, measured in terms of publication restrictions and secrecy provisions.[1] Such research results may be published and free for all to read, but without possibility to use the results, due to, for example, patents or database rights. If so, the benefit of the publicly sponsored research for the public is reduced to spillover effects only. If the research results are secret, then there are no spillover effects. These issues are often overlooked in discussions on the public value of science and discussions on research policy (David, Hall, and Toole 2000; Rothaermel and Thursby 2005).

The terms of agreements in collaborations can be so complicated and entangled that they hinder collaboration and cannot inform policymaking and management (Jarvenpaa and Välikangas 2014, 72,73). Policymakers lack the tools for spotting emerging knowledge monopolies. They provide public sponsorship to research without governing the future openness of the knowledge flow to society. Research managers in both industry and universities engage in collaborative research without a clear

[1] We use secrecy and confidentiality as synonyms. In a contract the clause that defines the parties right to require information being secret, the heading is often "Confidentiality".

understanding of the agreed openness and access to the research results. The problem is imminent as a transformation of research and innovation is called upon to address the societal challenges of our time. We present results from empirical research on how collaborative research projects between universities and industry agree on the openness and access to their results. We then discuss how this new understanding may have a profound impact on the governance of collaborative research. Such governance includes both how managers see the scope of the research projects as well as how a public funding body or an organisation view their portfolio of collaborative research projects.

Grillitsch et al. (2019) conclude that the literature on system innovation policy needs to engage with theories focused on actor, networks and institutions. To facilitate ex-ante negotiations, and to combine theories on different levels, policymakers and research managers must reconsider the contractual frameworks for collaborative research. We conceptualise such reconsideration and demonstrate a novel method for managing openness, as we spot possible knowledge monopolies ex-ante and ask what characteristics promote openness (Knut J Egelie et al. 2019). Our exploration builds on detailed studies of the collaboration agreements in 484 publicly sponsored research projects. All these projects include public research organisations and industry. As an illustrative example, we demonstrate how we applied the method to an institute-led Horizon2020 project comprising universities and industry.

From the issues above, our research question is:
How is the societal utility of collaborative research results affected by the governance of openness? Openness may depend on the industry or other project characteristics. Thus, our research objective is to empirically investigate if there are characteristics of the research projects that ex-ante of the research results, characterise the contractually agreed openness.

Our analysis builds on the contractual terms of 484 publicly sponsored collaborative projects between universities, industrial partners and research institutes. We analysed their consortium agreement in terms of the agreed openness and access to the research results.

2 Background

2.1 Openness versus access

The term "openness" has been used in many connotations. "Open innovation", "open science", "open business models", "open source" and lately "open access" are some of the concepts that claim openness. Bogers et al. (2017) review the open innovation concept and point to how it has evolved from a firm centric distributed innovation process managed across organisations to become a term for a wide range of connected concepts that include public governance, ecosystems and human behavioural. Still, a managed and distributed flow of knowledge is the core of open innovation. However, the knowledge that flows need not be open. It could, for example, be licensing that includes trade secrets. Bogers (2011) describes the tension field between collaborators in open innovation as a balancing act between knowledge sharing and protection. Laursen and Salter (2014) point to the same paradox of openness. They connect the openness of the firm to the appropriability methods managers use and how that orients the firm towards external innovation process actors. Lazzarotti et al. (2017, 468) review the empirical studies on openness in different industries. They find no definite answers. In these studies, the openness is not the openness of the research results, but the openness of the firm and the innovation process. This distinction between openness of the firm and openness of knowledge, such as research results, is easily lost in the grand discussions on openness. However, the lack of associations between industry and firm openness inspired our research objective to investigate associations between the openness of research results and industry.

In legal terms, more specifically used in contractual regulations, one vital distinction between openness and access is how patents and copyright may provide control of access to open knowledge. Even if the knowledge can be found, read and understood, it may not be accessible for commercial use (Walsh and Huang 2014; Long 2001).[2] An often-used clause in university and public research funding organisation agreements is related to further freedom to research and to disseminate the research. Public open access is essential and even trumps commercial use and possible commercial profits. The term “Open Access” coins this differentiation in that an open access publication can be found and read, and that the copyright licence is open, so it allows royalty-free reproduction. The free right to reproduce the verbatim text and figures is a sort of access to the research results. However, if the research results are technical, there might be patents that can stop the commercial utilisation of the research results. Thus, an open-access publication implies openness, but not necessarily access.

As an example, McNie, Parris, and Sarewitz (2016) presents a typology to “inform discussion, design and implementation of research”. The aim is to overcome the epistemological and cultural differences between academia and industry, often discussed as basic versus applied science. The proposed typology is nuanced with three activity areas: “Knowledge Production, Learning & Engagement and Organizational and Institutional Processes”. These are again divided into 15 attributes, each with a spectrum of research criteria spanning from “science values” to “user values”. Appropriation or control of the knowledge is not discussed in this typology. In other words, even if user values are dominating in an analysis building on this typology, it is not revealed if users can utilise the knowledge in commerce or even find the knowledge if searching.

[2] Firms may take their chances and not bother with other’s intellectual property rights. It can make make sense startegically to infringe, and prepare for a possible infringment lawsuit that may never come.

Knut J Egelie et al. (2019) address the issue of openness in research results and propose a typology based on a study of contracts in publicly funded life science research projects. They score the contractual provisions in terms of openness and access. Openness is whether the results are unrestricted, that is published, or restricted and thus confidential. Access is either concentrated or dispersed. Dispersed is typically non-exclusive licensing, concentration could be a patented technology that is not shared. The projects can then be placed in the resulting two-by-two matrix, as shown in Figure . This method builds on collaborative research projects, but it could be applied to any set of research or development projects.

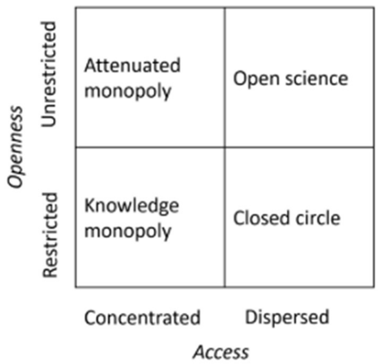

Figure 1 A tool for understanding the effects of contractual clauses, adapted from Egelie et al. (2019).

Behind this model is the debate on the transformative technology CRISPR. The clustered, regularly interspaced, short palindromic repeats (CRISPR) and the associated protein (Cas9) system is a powerful new technology platform for genome editing. Access to such technologies can be concentrated and governed by a few hands. Access to and utilisation of the technology depend on the intellectual property management and contractual terms devised by the technology owners. Thus, the agreement terms for research collaborations between universities and industry are essential for academic knowledge to be transferred to the public. Industry benefit from accessing scientific knowledge that they can use to anticipate future research problems in new technological areas. The identity of the technology owners, the technology coverage of their appropriation mechanisms, such as patents that have been filed for different components, and the geographical distribution of those appropriation mechanisms all influence future access to the technology. A proposition by Knut J Egelie et al. (2019) is that if the universities had analysed the collaborative research leading to CRISPR with a similar model, there could have been more attention earlier to the possible formation of knowledge monopolies. Patents and unknown future licensing models are issues with the CRISPR platform that affect the public utility of the research results. There is an ongoing patent dispute, involving exclusive licensing creating uncertainty about the eventual license terms for commercial use of the research results (Sherkow 2017; Knut J Egelie et al. 2018).

There are differences between industries in how openness is managed. In the industry of information and communication technology (ICT), the 5G technology platform (the fifth-generation mobile network, the basis for the "Internet of Things, IoT) uses a model from the previous collaborative efforts of developing networks. Technology ownership is handled through extensive cross-licensing through patent pools. The regime has invented new mechanisms such as the definition of "Standard Essential Patents" (SEPs)[3] and licences under "Fair, Reasonable and Non-Discriminatory" terms (FRAND).[4] The system regulates openness and access, but not without tensions (NGMN Alliance 2015; Heiden 2017; Teece 2018b).

Another example is in the energy sector. There is an evolution where the network market effects that guide the ICT sector now become more prominent.[5] The Smart

[3] SEPs are patents that in important markets cover one or more essential function of a standardised technology. The patent claims will read on one or more specified and mandatory parts of the standard.

[4] A FRAND declaration is a voluntary commitment from the SEP owner to a standardisation body that license terms will follow common rules on non-exclusive non-discriminatory licensing. In the case of disagreement for example on the value of the patented technology in a mobile phone, a court of law may consider this commitment and for example refuse a preliminary injunction to stop the sales of the phones.

[5] The systemic value of the network increases with a squared function of the number of users, as for communication networks. Metcalf's Law states that the value of a network grows as the square of the number of users. The growth of for example the value of Facebook has followed this law (Metcalfe 2013).

Grid, where energy production is a system involving products and services from many actors, is a technology platform that relies on standardisation. Both public and private actors are engaged (J.-Y. Ho and O'Sullivan 2019). The effect of standards is not only present in high-tech industries but also in for example, agriculture. Manning and Reinecke (2016) show how private standard-setters such as the Rainforest Alliance and Fairtrade affects agriculture and the coffee-sector. Standardisation allows for regulations on soil conservation practices and the abolition of child labour. Other industries have yet to introduce sustainability in their standardisation processes. Future standards on mobile networks could address sustainability. If universities hold SEPs, they could require adherence to sustainability terms for a license. A prominent example could be to follow the coffee industry and deny a license if a manufacturer depends on the use of child labour.[6]

Thus, industries differ in how to develop platforms and control these in terms of intellectual property. For some platform technologies, for example, biotechnology companies, trade secrets are potentially their most powerful form of innovation appropriation (Sherkow 2016). For other industries platform innovation interaction is more important and intellectual property control require other mechanisms (Gawer 2014).

2.2 *Top-down and bottom-up*

A long tradition of innovation policy supports the broad statements in our introduction. Innovation studies point to both the informal and formal elements of the innovation systems. An example of formal elements is how the legal system facilitates agreements through contract law (Fagerberg 2016; Lundvall et al. 2002). The national laws and international treaties and trade agreements regulate how the parties perform collaborative research. The regulations include the level of financial support

[6] Cobalt is vital in the Lithium-Ion batteries in mobile phones. Most cobalt is mined in the Democratic Republic of Congo. Amnesty International reports that the government there will eliminate child labour in the mining industry by 2025. Most phone manufacturer now lists the sources of their cobalt (Amnesty International 2017).

given by the public to research collaborations, where public money complements the capital markets (Hyytinen and Toivanen 2005). The regulations also interact with how the universities get funding from privately sponsored research. The different set of norms may lead to inconsistent policies for licencing technology out and for the universities demand for licencing-in research platforms. Also, collaborative research projects in newly industrialised countries and emerging industries are less likely to be sponsored by the public (Freitas, Marques, and e Silva 2013; Mowery 2007).

To mitigate the many challenges the public sponsoring bodies design research programmes that include normative templates that guide the formation of the collaborations. Large receivers of funds jointly develop some of these templates. An example is the DESCA organisation that develops a contract template for EU-funded projects in its Horizon2020 programme. There are also model contracts provided on a national level, such as the UK "Lambert toolkit". In other cases, the sponsoring public organisation has a set of optional templates or guidelines. The RCN provides a set of templates. The EU Commission provides guidelines for consortia contracts in the Horizon2020 programme. None of these templates or guidelines has clauses aimed at the formation of platforms or ecosystems (Eggington, Osborn, and Kaplan 2013; DESCA 2017; The Research Council of Norway 2019; European Commission 2015).

This top-down process from the policies, through templates, forms the actual contracts in the many research collaborations. The negotiations between the parties use the framework of policies and templates, but the process is bottom-up: The parties bring their background intellectual property, that could be the results of previous collaborative projects, to the table and negotiate freely within the frames of their organisations' policies. They agree on contracts, that reflects the outcome of the negotiations. These contracts are then the initial documentation on how the collaborating partners envisage the access to and the utilisation of the research results. The detailed provisions, as well as the strategic intellectual property policy of the collaboration, are usually confidential. The contracts are a natural source of information on the results of the negotiations, but due to the confidentiality requirements, they have, up to now, not been subjected to research studies (Granstrand and Holgersson 2014; H. Stevens et al. 2016; Czarnitzki, Grimpe, and Toole 2015a; Perkmann et al. 2013).

Prior research shows that industry partners that sponsor academic research or is a partner in collaborative research may use secrecy in the form of trade secrets as an appropriation mechanism, that is as part of the governance of the innovation. The use of secrecy conflicts with the normative openness of public research institutes, as well as with the capability academic institutions have for keeping trade secrets. This conflict leads to a need for balancing the contractual provisions on openness, often in terms of confidentiality and trade secrets on one side and publication and disclosure on the other (Blumenthal, Campbell, et al. 1996; Cohen et al. 1998; Joshua S Gans and Murray 2012; J.A. Evans 2010).

2.3 Incomplete contracts and the disassembly problem

The current “Framing 2”, as discussed by (Schot and Steinmueller 2018), and also the “Mode 2” introduced by Gibbons (1994) points to the greater role of agency and how ingenuity is needed to transform the collaborative, often pre-competitive research into a competitive marketplace. In this transformation industry and academia interact; and there are no firm answers to the positive or negative impact of commercialisation or industry impact on academic publishing (J.A. Evans 2010; Gulbrandsen and Smeby 2005; Perkmann et al. 2013). The research collaborations are formed in the initial phase of innovation. The partners negotiate the terms for utilising the research results. As the outcome of research by nature is uncertain, these contracts are incomplete. From contract theory, the parties can agree on ownership rather than detailing all rights of control in a contract. However, the parties do not have all the information about the outcome of the negotiations, that is the research result. Then, the solution is to renegotiate the agreement when the parties know more about the results (Hart and Moore 1988; Grossman and Hart 1986). The literature on the renegotiation of collaborative contracts is scarce. Rosenkranz and Schmitz (2003) study dynamic R&D alliances building on Aghion and Tirole (1994), who discuss the effects of allocating ownership to innovations. Both the magnitude and frequency of innovations is affected by the framework of incomplete contacts. There are also studies on "Public-Private Partnerships", that is large scale infrastructure or public service projects. Examples are health services and road constructions. Here renegotiations are commonplace, and contracts are understood to be incomplete, in that they concern the development and may last for 30 years or more (Sarmento and Renneboog 2016). In both the "Framing 2" and the "Framing 3" context for science, technology and innovation policy, there could be interesting parallels in how contracts can be renegotiated.

During a collaborative research project, the parties assemble knowledge, controlled by intellectual property rights through contractual agreements and provisions. The results are likely to be used in the next phase of an innovation process or become part of a platform that can spawn many new products and services. The intellectual property rights will then be reassembled in another form. However, before that can take place, the initial project must disassemble the rights and make them available (Granstrand and Holgersson 2014). That is, there must be access to the research results. In the model by Knut J Egelie et al. (2019), "Access" is seen as either concentrated or dispersed. Access is controlled by ownership and by specific use rights to the research results, such as the right to use a part of it or use it for a given purpose, such as education or further research.

2.4 Industry and academic collaboration

Perkmann et al. (2013)[7] discuss the collaboration between industry and academic institutions in terms of academic engagement. This engagement is an alignment of the academic role with the commercial purpose of the collaborating party. Both individual and organisational levels are essential, but the individuals are the ones who are engaged. Several studies confirm that the industrial partner in a collaboration will try

[7] Interestingly for our study they point to university records on contracts with industry as an "ideal source of information" but rarely available due to the commercial considerations by the university.

to govern secrecy and require that a sponsored academic researcher does not publish all results (Bernal 1939; Blumenthal et al. 1996; Louis et al. 2001; Czarnitzki, Grimpe, and Toole 2015a).

Both universities and to some extent research institutes engage with commercialisation by setting up organisational structures, often called “technology transfer offices” (TTO) or “innovation offices”. These offices acting on behalf of their organisations, handle valuable research results in a commercial setting by licensing them out or assigning them to the existing industry or new spin-out companies. Holgersson and Aaboen (2019) observe that the research literature describes most TTOs as acting in an “appropriation mode”. The TTO’s focus is to get control over the technology using intellectual property, and their performance is measured by the numbers of patents and contracts. Opposed to this, the TTOs should move to a “utilisation mode” where the focus is on the governance of the innovation, rather than protection. Only then can the aim of openness in the technologies the universities’ transfer of technology be optimised in a move away from maximising private value to maximising the welfare of the society. The practical consequences of such a change are illustrated by the narratives in (Petrusson 2016; Foss and Gibson 2015; Y.H. Lee and Graff 2016): The universities can drive innovation in a region. There are many ways of organising knowledge dissemination and entrepreneurial efforts. However, the universities must build structures that go beyond the TTOs to ensure the utilisation of the research results for the benefit of society. As part of this effort, some universities have professionalised the management of grants and research contracts and established Project Management Offices (PMOs). If the universities are to engage in the development of new technology platforms, this requires that they can identify and govern the knowledge and intellectual assets that are created within their organisations, and in the collaborations that are needed to develop new technology platforms and societal transformation. Thus, they need structures like TTOs or PMOs.

3 Method and data

3.1 Research design

The Norwegian government allowed us, under a confidentiality agreement, to study the contracts of collaborative research projects funded by the Research Council of Norway (RCN). We defined technology clusters and coded each project to belong to one of biotechnology, energy, ocean, ICT, engineering or climate (a broad category) as described in Table . We followed to a large extent the structure of the research programmes of the RCN in the coding.

Cluster abbreviation	Description of technologies included in the cluster	Number of projects
BIO	Lifesciences, Biotechnology, Aquaculture, Forestry and Agriculture if biotechnology,	162
ENERGY	Oil and Gas, Hydropower, Solar power, Windmills	140
OCEAN	Shipping, maritime operations, sub-sea installations and robots – the mechanical part of aquaculture	62
ICT	Information and communication technology	42
ENGINEERING	Mechanical, nanotechnology (if material sciences and not biotechnology), material sciences, mineral mining	12
CLIMATE	Climate, polar (Arctic, Antarctic) projects, transport	66

Table 1 Technology clusters and number of projects

We had 484 projects in our dataset. Initially, we randomly selected 1000 projects with the criteria that they had at least one university and one industry partner and start date in 2009 or later. We then dismissed projects without archived, readable contracts or provisions on intellectual property or ownership of the research results. We checked that the resulting set of 484 projects had a similar distribution of project budget and the number of parties as to the dismissed projects.

3.2 *Data collection*

We further registered data, such as the project budget and the RCN funding, as well as if the project coordinator was a university, research institute, commercial entity or public body. The project coordinator has a separate agreement with RCN and then agrees with the other parties to the collaboration in a separate consortium contract, or bilateral contracts. We registered if an agreement was based on an RCN template. We also noted if the agreement had special provisions that allowed for secrecy as an appropriation mechanism. We looked for, but did not find, provisions on renegotiation or aiming at forming platforms or ecosystems.

We scored the agreements with a 1 to 5 score for four variables concerning the research results: ownership, commercial use rights, publication rights and the right to require confidentiality. A score of 1 indicates that the industry partner will own, have use rights, may limit publication and can keep the results as trade secrets. A score of 5 indicates that the ownership will be with a university, the use rights will be available on a non-exclusive basis, all results will be published, and no results can be kept secret. We simplified leaving out research institute ownership in the scoring. We justify this with reference to Gulbrandsen (2011) that discuss research institutes as hybrid organisations, and how they try to align with both industry and academia.

In addition to the four variables in our study, we scored four additional variables, that did not show enough variance to be of interest: background, use rights for research and education, liabilities and warranties. The right to use the background is seen as essential in most collaboration agreements. This is the knowledge and rights that the parties bring with them, like software and patents. As we scored, we noted that although it is important to document these rights, all agree that they belong to the contributor. For the rights to use the results in further research and education, not surprisingly the universities and research institutes usually get these rights, that are core to their motivation. As for liability and warranties – this is to what extent the parties warrant that they can deliver and agree to be liable or indemnify the other parties if something goes wrong. We found outliers, like universities indemnifying commercial partners regarding the research results not infringing third parties' patents. However, reading the agreements, these seemed more like managerial glitches than real commitments. Thus, we focused on the ownership, use rights, publication and confidentiality, in our analysis of the data.

3.2.1 Variables

We created dummy-variables for access and openness. Both are used for the two-by-two matrix. Openness is the dependent variable in our linear regression model. The first variable, access, is assigned a value of one for dispersed ownership or dispersed use rights (that is the commercial rights to use of the foreground, the research results) and zero otherwise. All other scores either indicate concentrated ownership and use rights on the side of industry or university, or they lean towards concentration. The variables for publication and confidentiality correlate from their definition but maybe score differently in a single project. We create the second, ordinal dummy variable openness, by running a factor analysis to aggregate the two variables. We also tested models for the linear regression discussed below, using the sum of the publication and confidentiality scores and got nearly identical results.

We explain the independent variables in Table 2. We have 484 observations for all the variables.

Independent variable	**Description**
Industry ownership	Scores of 1 or 2 from the scoring of ownership, binomial
Joint ownership	Score of 3 from the scoring of ownership, binomial
Industry use rights	Scores of 1 or 2 from the scoring of commercial use rights, binomial
Joint use rights	Scores of 3 from the scoring of commercial use rights, binomial
Share of RCN funding	The share of public funding of the total budget, between 0.09 and 1.00
Industry partners	The share of industry partners in the project, between 0.07 and 0.95
University partners	The share of university partners in the project, between 0.04 and 0.89
Institute partners	The share of institute partners in the project, between 0.00 and 0.71

Number_of_partners	The number of partners. Minimum is 2, maximum is 40.
Univ. coordination	Coordinated by a university or not - binomial
Research project	Basic research project (as opposed to an innovation project) - binomial
Energy	A technology cluster, binomial
Engineering	A technology cluster, binomial
ICT	A technology cluster, binomial
Ocean	A technology cluster, binomial
Climate	A technology cluster, binomial
Total budget	Total budget in million NOK (10NOK is around 1EUR, minimum is 0.2, maximum is 430.6 . Natural logarithm used in regression
Year 2009-2011	Started in 2009-2011 - binomial
Year 2012-2014	Started in 2012-2014 - binomial

Table 2 Independent variables

3.3 *Data analysis*

We used the software Stata 15.2 for the statistical analyses. We read all the agreements manually from electronic copies in pdf format, scanned by RCN. The scoring and project data were recorded in spreadsheets.

3.4 *Descriptive statistics*

There are agreements between 3944 parties to 484 collaborative projects. All projects were funded by the RCN between 2008 and 2017. In the projects, there are 988 university parties (not single universities), 150 public bodies (like a county or a specific branch of government), 613 research institutes and 2193 commercial entities. The research institutes act as project coordinator in 38 per cent of the cases, whereas they are only contract parties in 16 per cent of the cases. The share of industry partners coordinating projects is skewed the other way, whereas universities coordinate comparable to their share of participation, as shown in Figure 3. In our analysis, we made the simplification of regarding research institutes as in-between universities and industry, as discussed in clause 2.4. Based on Figure 3, a question for future research is how research institutes act as project coordinators. It could be that they to a large extent, do the work on behalf of industry an align with their objectives.

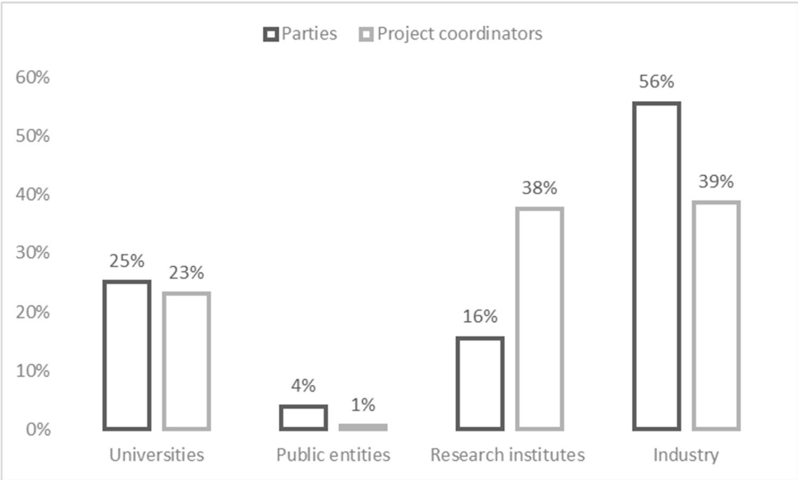

Figure 3 Agreement parties and Project coordinators

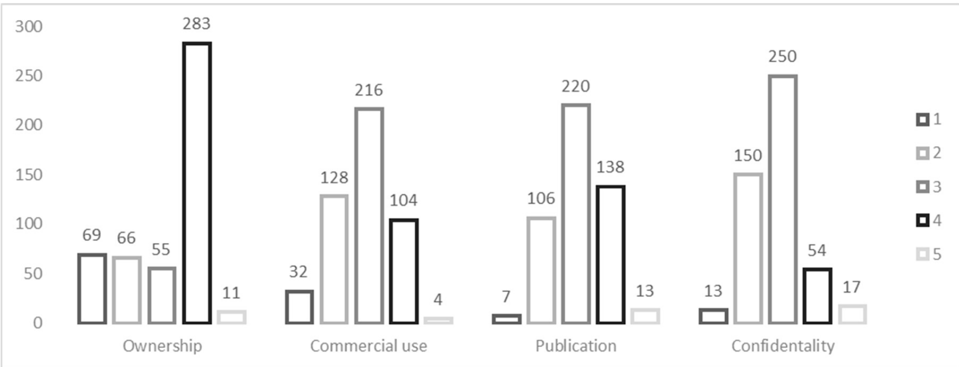

Figure 2 Scoring results.

Figure 2 shows the results from the scoring, see the Appendix - scoring table. A score of "1" indicates industry ownership, use rights and control of publication and confidentiality. "3" is a joint or balanced outcome. "5" is university ownership. We note that the preferred ownership agreement is "4", that is dispersed ownership where the universities have the ownership to their results. The three other variables are more balanced, but with publication skewed towards universities requirements and confidentiality skewed towards industry's need for confidentiality.

3.5 Empirical analysis

First, we are interested in characterising the RCN funded portfolio of projects regarding their contractual provisions on access to and openness of research results. For ownership of the research results the ownership is concentrated to industry in 28 per cent of the projects, and with universities in 61 per cent. Only 11 per cent of the projects have dispersed ownership. For commercial use right, the industry partners have 33 per cent, the universities have 22 per cent. In 44 per cent the use rights are dispersed. The indication is that ownership is concentrated on universities, whereas commercial use rights are dispersed.

We then used the dummy variables of openness and access to place the projects in the quadrants of the two-by-two matrix from Figure . The results are in Figure 4.

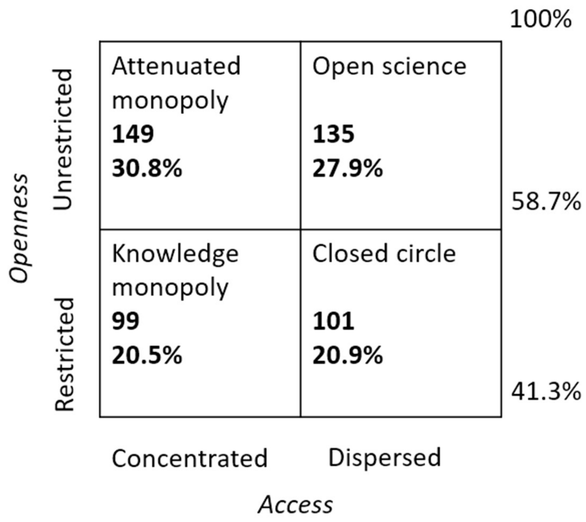

Figure 4 The projects placed in the matrix from Figure 1

We find that 20.5 per cent of the projects in the RCN portfolio may form knowledge monopolies, whereas 27.9 per cent have provisions that indicate that the research results may be available as open science. Openness is unrestricted for 58.7 per cent of the projects in the RCN portfolio.

3.6 *Models*

We prepared four models; the results are in Table 3. First, we used the openness variable (the combination of confidentiality and publication) as a dependent variable in a linear regression, without the scored variables. Then we tried with the ownership and foreground variables as explanatory variables. The results were consistent between the two models. We then prepared models 3 with publication and 4 with confidentiality as the dependent variables. We used ordered probit, as the variables from the scoring are ordinal. The results were consistent with the two first models, and gives more insight in which of the scores contributed the most. The publication and confidentiality scores correlate, but may have different importance for groups of projects.

As expected, if industry has ownership or use rights, this is negatively associated with openness. Interestingly, we also find that joint foreground is negatively associated with openness. We do not have a significant result through the models for the funding share variable, nor do we have that for most of the technology sectors, that is the fields of industry except for the technology cluster "Climate". From Table this cluster includes projects in the fields of climate, Arctic, Antarctic as well as transport, except shipping. The field of the industry then seems unrelated to openness. As expected, the association here is strong and positive. Also, if the project is defined as a basic research project, the association with openness is as we expected, strong and positive.

	Model 1	*Model 2*	*Model 3*	*Model 4*
	linear regression	linear regression	ordered probit	ordered probit
	Openness	Openness	Publication	Confidentiality
Industry ownership		-0.249**	-0.287***	-0.191
		(0.103)	(0.095)	(0.153)
Joint ownership		0.003	0.065	-0.061
		(0.172)	(0.191)	(0.189)
Industry use rights		-0.390***	-0.358***	-0.446***
		(0.118)	(0.138)	(0.126)
Joint use rights		-0.348***	-0.393***	-0.292***
		(0.093)	(0.113)	(0.097)
Share of RCN funding	-0.001	-0.002	-0.002	-0.002
	(0.002)	(0.002)	(0.003)	(0.003)
Industry partners	-0.464*	-0.496*	-0.149	--0.496*
	(0.265)	(0.286)	(0.420)	(0.472)
University partners	0.216	0.018	0.268	-0.33
	(0.389)	(0.399)	(0.440)	(0.555)
Institute partners	0.171	0.049	0.351	-0.339
	(0.377)	(0.403)	(0.435)	(0.657)
Number of partners	0.027**	0.017*	0.020*	0.015
	(0.010)	(0.009)	(0.011)	(0.010)
University coordinator	0.230**	0.199**	0.202	0.189
	(0.102)	(0.094)	(0.137)	(0.149)
Research project	0.307***	0.265**	0.383***	0.113
	(0.105)	(0.109)	(0.134)	(0.149)
Energy	0.024	0.06	-0.056	0.198*
	(0.087)	(0.100)	(0.104)	(0.106)
Engineering	-0.462	-0.435	-0.112	-0.794*
	(0.349)	(0.385)	(0.407)	(0.407)
ICT	0.03	-0.03	-0.284**	0.245
	(0.106)	(0.129)	(0.123)	(0.150)
Ocean	0.161*	0.132	-0.069	0.343***
	(0.090)	(0.115)	(0.164)	(0.108)
Climate	0.267**	0.243**	0.292**	0.198*
	(0.108)	(0.116)	(0.139)	(0.117)
Total project budget	-0.143***	-0.135***	-0.068	-0.190***
	(0.046)	(0.042)	(0.065)	(0.036)
Year 2009-2011	-0.355**	-0.255*	0.032	-0.588***
	(0.136)	(0.137)	(0.173)	(0.159)
Year 2012-2014	-0.406***	-0.349***	-0.17	-0.537***
	(0.101)	(0.090)	(0.104)	(0.104)

Constant	1.391***	1.898***		
	(0.456)	(0.438)		
/				
cut1			-3.205***	-5.044***
			(0.807)	(0.552)
cut2			-1.664**	-3.339***
			(0.784)	(0.554)
cut3			-0.353	-1.681***
			(0.769)	(0.555)
cut4			1.248	-0.871
			(0.821)	(0.557)
(Pseudo) R2	0.13	0.17	0.06	0.08
N	484	484	484	484
F or LR/Wald chi2	8.8	18.21	211.689	498.621
P-value	0	0	0	0
Log likelihood	-651.887	-641.082	-551.277	-517.121

** p<0.10, ** p<0.05, *** p<0.01*
Reference categories: university ownership, university use rights, biotech

Table 3 The four models

University coordination of the projects associates positively with openness, as do the project being classified as a basic research project. There is also a weakly significant association to the number of participants. The total budget associates negatively with openness, as do the age of the projects. The projects started earlier than the last three years of our study, associated negatively with openness, indicating that the more recent agreements in the RCN portfolio to a more considerable extent promote openness.

The publication and confidentiality variables in models 3 and 4 have significant dependencies that do not show in models 1 and 2 with the openness variable. Table 4 presents an excerpt of these, together with the cases where only the openness variable had significance with p<0.10.

	Model 2 - Openness	*Model 3 - Publication*	*Model 4 - Confidentiality*
Industry partners	-0.496*		-0.496*
Number of partners	0.017*	0.020*	
University coordinator	0.199**		
Research project	0.265**	0.383***	
Energy			0.198*
Engineering			-0.794*
ICT		-0.284**	
Ocean			0.343***
Total project budget	-0.135***		-0.190***
Year 2009-2011	-0.255*		-0.588***
Year 2012-2014	-0.349***		-0.537***

*Table 4 Excerpt for the publication and confidentiality variables (where the score 1 requires secrecy and 5 no requirement for secrecy) - * p<0.10, ** p<0.05, *** p<0.01*

From Table 4 the Industry partners variable show that a higher number of industrial project partners, as expected, associates with a lower score on confidentiality (that is more secrecy by default, see the Appendix - scoring table). However, a high number of participants associates with more publication. If the project coordinator is a university, this associate with openness, but not significantly from any of publication or confidentiality. Requirements for publication as expected, associate with the project being a research project. As for the project budget, the association to lower openness originates from the increased confidentiality. The indicated openness of the RCN portfolio starting in 2014 or earlier was lower than for more current projects, with confidentiality as a significant contributor. Thus, the collaboration agreements of the

RCN portfolio have become more open over time, associated with fewer requirements for confidentiality.

For the industry clusters, energy and ocean are associated with fewer requirements for confidentiality, as for climate in Table 3. Engineering is associated with more confidentiality. The ICT cluster is negatively associated with publication, meaning that in these projects, there are more agreements on restrictions or delays on publication but not requirements on confidentiality.

4 Illustrative case – openness in the AlSiCal consortium

We asked how the societal utility of collaborative research results is affected by the governance of openness and studied the openness in a portfolio of research collaboration projects. The method we used is of value also for the governance and management of a single collaborative research project, as we illustrate in the case of an EU-funded project. AlSiCal is a research and innovation project aiming at making the mineral and metal industry more sustainable and environmentally sound. The consortium will research and develop a new technology platform. The starting point is a process patented by two of the consortium partners. The new process gives no CO_2 emissions and no problematic by-products as from the current process. The consortium comprises 16 partners from nine countries, two outside Europe. There are four universities, three research institutes and two industry associations among the partners in addition to seven commercial firms. The EU's Horizon2020 programme funds 100% of the AlSiCal project with 5.8 million euro over four years, beginning in 2019 (Aranda 2019).

We analysed the grant agreement between the project parties and the EU Commission, together with the consortium agreement between the parties. The first gives a normative framework for the latter, that uses the DESCA template (DESCA 2017). This template includes clauses on access and openness corresponding to the Appendix - scoring table.

We then scored the consortium agreement. The ownership and use rights to the results are dispersed. The openness is restricted, as there are confidentiality clauses that could limit the flow of knowledge out of the project. However, within the project, there are non-disclosure clauses that ensure a free flow of knowledge between the parties. Using the two-by-two matrix of Figure , we placed the project within the "Closed circle" quadrant, as shown in Figure 5. The arrow indicates that the project steering group may, within the scope of the consortium agreement, decide to make the project results available to the public without restrictions. If the patents that are part of the background information in the project, together with the research results are licensed out on FRAND-like terms, and no results are kept a secret, then the research results would qualify as "Open science".

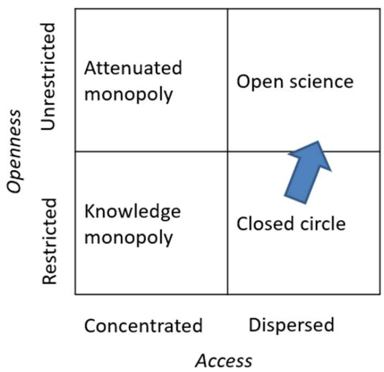

Figure 5 AlSiCal classified as a closed circle

As the project started in late 2019, they do not know how the knowledge produced may be of best use to society. It could be that a closed circle is a preferred way of launching a new platform technology, establishing standards and creating technology platform. The technology that AlSiCal develops is disruptive in that it seeks to replace the Bayer process that was invented in 1888 and has been dominant since then (Habashi 1995). If the AlSiCal project succeeds, they may form an ecosystem that gives a greener mineral and metal industry. The parties to the project may benefit from understanding the project as being a closed circle with the option of moving towards open science and discussing possible orchestration. Policymakers and public funders may use this insight to orchestrate further efforts on developing a new ecosystem, with the needed standards for technology and sustainability.

5 Discussion and conclusion

We focused on the openness variable and used the access variable solely for placing projects in the two-by-two matrix in Figure 4. When considering a portfolio of research projects regarding the public benefit from the research results, then openness matters more than access. If the research results are secrets, such as trade secrets, then they are not accessible to others than those who belong to the knowledge monopoly or closed circle, simply because the secrets cannot be found by search. If the access is restricted, but the knowledge is available to the public, such as for patented technology in an attenuated monopoly, then the government can introduce measures to make the technology available. One example is through financial incentives where a public body rewards licensing, for example, through standards. Another example is that most jurisdictions have laws on compulsory licenses for copyright or patents. However, Henry and Stiglitz (2010) point to how the implementation of trade agreements, such as TRIPS, have hindered developing countries in using compulsory licenses.

In the AlSiCal-case ownership of the results is dispersed, and the consortium agreement allows for trade secrets. Thus, the research results fall into the closed circle category. A critical modifier is that this possibility for trade secrets is not a secret by itself. The consortium is open versus the public sponsors. The agreements allow that they may choose trade secret licencing if this for a period, is the optimum way of transferring the knowledge and initiating the change to a greener industry. In that way, the openness of the research results is already high and in line with the objectives of the EU Commission when they sponsor a project 100 per cent. Keeping the option for trade secrecy ensures the possibility for a meaningful renegotiation between the parties, as we presented in clause 2.3 Incomplete contracts and the disassembly problem.

As our research objective, we set out to investigate if there are characteristics of the research projects that ex-ante of the research results, characterise the agreed openness. From the RCN portfolio regression model, we did not find any significant difference for openness between fields of industry, except for the climate cluster. As we discussed, there are differences in the standardisation and business models for ICT and biotechnology (that is the reference), and we had expected significant differences in associations between the field of industry and openness. An explanation may be in the normative strength of the contract templates that we also discussed in clause 2.3. If the projects copy-paste the templates, there will be little variations. Another possible explanation is that the openness issue applies to all industries alike and is independent of business models and academic traditions. The number of universities participating in a project does not associate with openness but having a university as project coordinator does.

The excerpt in Table 4 gives some more details on the variations between technologies for confidentiality and publication. The results indicate that policymakers should consider normative templates that reflect the business models for the industries in a programme. On the association between budget size and requirements for confidentiality in the agreements, our study confirms the prior research of Louis et al. (2001) who found that the larger the scientists' research budget is, the more likely they are to deny other's access to their results and to be denied access to other scientists' work.

We analysed the openness of the research results, and not of the participating firms or organisations. However, the lack of differences between fields of industry for firms, as reviewed by Lazzarotti et al. (2017) is then reflected in our results for the agreements on research results, except for the strong and positive association with the climate cluster.

Looking more into our analysis of the set from the complete RCN portfolio, we see from our two-by-two matrix that 20.5 per cent of the projects may become knowledge monopolies. In the project period we studied, the RCN granted some 19500 projects with around 640 billion euro.[8] We do not know if any of these projects ever become knowledge monopolies. We only know that the consortium agreements allow for monopolies to form. A simple precaution to mitigate this societal risk could be for the sponsors to discuss the need these projects have for low openness. Also, we show that the openness of the more recent project is higher; but we found a negative association between openness and the total budget of the project. Thus, creating incentives for more universities to coordinate research projects and having smaller projects in terms of total budget may increase openness in a portfolio.

In the AlSiCal case, we showed how analysis of the consortium agreements using the discussed two-by-two matrix might assist the project manager and the steering group in creating an open technology platform. For the RCN portfolio, we apply the tool on a diverse set of research projects and show that a large percentage of the projects should be discussed in terms of their openness and thus, their possible contribution to societal transformation and sustainability. We started our paper with the Lund declaration and the Schot and Steinmueller (2018) suggestions for a new framing for innovation policy. Our complementary suggestion is the bottom-up approach of improving the framework of the research collaboration agreements.

It could, however, be so that the legal clauses have less importance than the actual trust between the parties and the informal contacts in the project and its steering group. For example, prior experience from collaboration builds trust and lowers the barriers for cooperation. High technological complexity with tacit knowledge may reduce trust (Bruneel, D'Este, and Salter 2010; Bruneel, Spithoven, and Clarysse 2017). For reasons of confidentiality, the terms of our study did not allow us to contact the projects and interview the parties on the trust among the partners. Future studies may use qualitative methods and benefit from recent research, such as Joshua S. Gans, Murray, and Stern (2017) that theoretically explore the tension between a firm's

[8] RCN grants are listed at https://bit.ly/39ccMUX

objectives and their researchers and discuss different disclosure strategies. Another interesting perspective is from Hewitt-Dundas, Gkypali, and Roper (2019) that show how learning from previous collaborations with customers and consultants, improve a firm's innovation from further collaborations with universities.

Measuring the impact of research is performed ex-post. Joly et al. (2015) present the ASPIRA framework for evaluating the societal impact of research with four types of impact pathways. Their next challenge is to "*draw on the knowledge generated by ex post evaluation to improve ex ante or in itinere analysis*". Our cases with the use of the two-by-two typology in Figure 2 demonstrate such an initial attempt of analysis that a sponsor could do before the research projects start or as a guide to a project steering group as the project operates. Further research could see if these ex-ante and ex-post typologies can be aligned and contribute to the understanding of sustainability in research results and the resulting technology.

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7 Appendix - scoring table

	ACCESS		OPENNESS		
	Ownership	**Commercial use rights**	**Publication**	**Confidentiality**	
1	Industry partner owns all IP and project results	Industry partner has exclusive use rights to all commercial use of IP and project results	All dissemination of project results is strictly controlled. No publications allowed	All information is by default confidential if not already public. No specified timeframe or other limitations	**1**
2	A specific party owns project results if based on own background, dominating contribution or own commercial interests. Otherwise jointly owned	All parties have by default exclusive use rights within specified field or non-exclusive, world-wide, royalty free in all fields	Project results must be published but could be delayed according to participants' needs	All project results and background information disclosed are by default confidential if not already public, limited in time	**2**
3	All project results are jointly owned. Separate agreements for commercial use rights	All parties granted non-exclusive use rights to all project results to be able to utilise own project result	Results shall be published, but publication must be sent to steering committee which could object and request modifications before publication	Project results and background information are confidential if marked, justified and limited in scope and time	**3**
4	A specific project partner retains ownership of all project results. Where several parties have carried out work	All parties have royalty free use rights, but only during the project period to results that are	Publications could be delayed due to patenting or other justified grounds, but according to national	Project partners must specifically request confidentiality. Information must be marked confidential,	**4**

	generating project results and where share of the work cannot be ascertained, they have joint ownership	needed to utilise own project result. Further use rights may be given upon request	laws. Clearly stated that results must be published within a time frame	time limited and approved by steering committee. Parties could refuse	
5	Academic partner owns all IP and project results	Only academic partner has specified use rights to project results	No publication restriction. Specified that results must be published	No terms on confidentiality specified	**5**

Research paper 4:

Trade Secret Establishment, Use and Management in SMEs

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Trade Secret Establishment, Use and Management in SMEs

Abstract

SMEs use trade secrets to create competitive advantages from knowledge exchange and open innovation. This paper builds on survey data from 3871 Norwegian SMEs with a novel set of questions: We introduced a differentiation between establishing and using trade secrets. We then added innovation success proxies, built probit models and found associations with indicators of innovation, export, management processes, contractual agreements and revenue. We propose how to set a baseline for future studies on the effect of the new EU and US legislation, and we contribute to management theory and practise on the SMEs' management of trade secrets.

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1 Introduction

There is little evidence about small and medium-sized enterprises' (SMEs) management of trade secrets. Also, the literature lacks a crucial distinction between preparing for secrecy, such as setting up a non-disclosure agreement, and using trade secrets, for example, in open innovation. These details matter, because SME managers use trade secrets as objects for licenses and contracts, and thus for knowledge exchange and in collaborations (Freel and Robson 2016; Thomä and Zimmermann 2013). As we discuss, a better understanding of trade secret management must include the distinction between preparing and using. Trade secrets are established when there is a clear and documented definition that delimits the secret and specifies how it is protected. Then they may be used or not. The two steps are important to understand how to manage the secrecy and combine it with other mechanisms. Improved trade secret management is an opportunity for creating competitive advantages and lower the risk when engaging in open innovation. The EU and the USA recently amended the legislation on trade secrets. The new laws define trade secrets and the requirements for misappropriation more clearly, as well as possible remedies and confidentiality during court proceedings (Linton 2016). [1] The EU and US policymakers believe that these changes will benefit innovation and in particular for SMEs: Trade secrets may become a better alternative or, as we discuss, complement to patenting. However, there is no baseline for measuring the improvements. There is also a lack of theory and understanding of the mechanisms involved. Our research questions address these shortcomings. We ask if there is a difference for SMEs between establishing and using trade secrets, both in numbers and in characteristics. We then ask if the SMEs use trade secrets for knowledge exchange through mechanisms such as licensing and innovation cluster participation. Finally, we ask if there are associations between SMEs establishment or use of trade secrets and management procedures.

[1] Courts of law have usually open proceedings. Thus, a trade secret could be disclosed there during a misappropriation case. A firm could lose their trade secrets if accusing another firm of stealing them.

Most surveys on innovation management have broad questions that are varieties of "do-you-find-secrecy-effective-to-your-innovation". These studies show how the majority of firms, large and small, find secrecy more critical than patents and trademarks for the appropriation of innovation. However, they do not discuss how the firms use secrets and how trade secrets are part of other mechanisms (Levin et al. 1987; B. Hall et al. 2014; Eurostat 2016).[2] For many SME managers trade secrets may be the preferred innovation appropriation mechanism, more of use than patents. Studies that address SMEs find that there are associations between secrecy and inbound open innovation. They often refer to secrecy as an "informal appropriation mechanism" applied in the knowledge transfer and licensing. The term "informal" is from the lack of legal registration of appropriation, such as there is for patents and trademarks, and not from lacking need of management and internal procedures. As we will discuss, the benefits of trade secret management and how it relates to both formal and informal appropriation is poorly understood (Freel and Robson 2016; Love and Roper 2015; Radicic and Pugh 2017).

Further, there are no consistent figures on the extent of trade secret management and how SMEs use trade secrets. The numbers in the literature on how many SMEs that manage and use their trade secrets vary widely. On the simple question "what is the percentage of SMEs that use trade secrets" there are answers in the literature spanning one order of magnitude, from seven per cent to 77 per cent, see Table . What matters, even more, is that previous research asks about issues that do not correspond to trade secrets as the new legislation in the EU and the USA now define them. Thus, this literature cannot serve as a baseline for studies on the effect of the new laws for SMEs. In brief, there has been an unrecognised difference between firms agreeing on the framework for confidentiality, firms establishing a trade secret by defining it and protecting it, and firms using a trade secret as an object for licensing or litigation. The

[2] This is not a complete list of prior surveys, but prominent examples with valuable contributions. As we discuss later, all surveys that build on the Oslo Manual will mix appropriation from trade secrets and the composite mechanism "lead time advantages".

use of a trade secret implies knowledge transfer, whereas establishment means only preparation for possible knowledge transfer. The distinction is essential to understand how SMEs manage trade secrets to innovate more successfully, how they prepare to join external networks, such as innovation clusters, and how they use trade secrets for knowledge exchange in open innovation.

We base our data on questions to 3871 SMEs, where we differentiated between the establishment and the use of trade secrets. Besides, we use grants of tax exemption for innovation, and capitalisation of research in the SMEs accounting as indicators of innovation. The SMEs we studied are all located in Norway, with a legal framework for trade secrets coherent with the new directive from the EU.[3] In our study, we find differences such as the SMEs establishing trade secrets but using them less for licensing and collaboration. Our new way of asking gives a better understanding of the management decisions in SMEs. We find associations between the establishment of trade secrets, the firms' procedures for intellectual property management as well as the early and late-stage innovation indicators. Since patents are well understood as an appropriation and knowledge sharing mechanism, we compare the use and establishment of trade secrets with the SMEs' use of patents. The SMEs use trade secrets more in early innovation and cooperative innovation within clusters. Trade secrets are used less than patents for licencing. We argue that this may change with the improved legal framework for trade secrets. Our study may serve as a baseline for further studies on the effects of this change and as a contribution to theory on trade secret management.

Next, we discuss relevant theory and define our research questions. We then present the data and results of regression analysis, before our discussion and the implications for policymakers, researchers and managers.

[3] Norway is a part of the European Economic Area and a part of the EU innovation system. Norway's legal framework on trade secrets follows the new EU directive and was similar before and during the survey. (Norwegian Government 2019).

2 Theory Leading to Our Research Questions

2.1 Trade secrets, the innovation system and SMEs

Policymakers in the EU find that trade secrets have great importance for SMEs.[4] The recent US federal legislation "Defend Trade Secrets Act" (DTSA) and the new EU directive on trade secrets address the need firms have for a harmonised legal framework (Congress of the United States of America 2016; European Commission 2016). When firms engage in open innovation, they can exchange information with others in the form of trade secrets. Trade secrets can be shared, for example, under a non-disclosure agreement (NDA), sold or licensed. Whenever a firm shares a trade secret or is entrusted one, the firm must manage the scope of the secret and the agreed terms for sharing. The management of trade secrets is different from the management of the many other mechanisms firms use to appropriate innovation and share knowledge: It is the only mechanism where publication is not possible. A patent will become public. The license to software under copyright does not depend on the secrecy of the source code. All other intellectual property (IP), like trademarks and designs, can or must be published, except trade secrets. Another interesting difference is that trade secrets arise from secrets and not legal constructs. A manager can successfully decide to keep information secret and work out how with the involved employees, without any knowledge of the law.

In contrast, the patent system consists of an intricate web of laws, rules and international conventions. It is hardly possible to successfully file a patent application without consulting a patent attorney. Patents do not exist without patent law. There are laws concerning trade secrets as well, and there are international conventions and trade agreements. However, these are only of interest in the case of misappropriation, if the secret is disclosed or stolen. In the case of successful trade secret management, there is no need for legal expertise. For a start-up with less legal resources than a large

[4] Even though trade secrets are important to SMEs, they are considered even more important by managers in large firms (EUIPO, 2017, pp. 29-34).

corporation, trade secrets appear to be an attractive alternative to patents for the appropriation of technological inventions. Besides, trade secrets have a role for commercially valuable information such as business strategy and plans, customer and partner information and unpatentable technical knowledge. The literature confirms how business managers and policymakers in general consider trade secrets to be more relevant to innovation than patents and other intellectual property (Levin et al. 1987; Cohen, Nelson, and Walsh 2000; Arundel 2001; Leiponen and Byma 2009; Gallié and Legros 2012; B. Hall et al. 2014; Eurostat 2016).

By contrast, patents are public, indexed and well-defined, and thus much more researched. Researchers can find exactly how many are owned by SMEs. There is a plenitude of literature and statistics on how SMEs use patents and how it affects their growth (EUIPO and European Patent Office 2019). Patent applications are usually also trade secrets before they are filed. They may continue to be secret for the next 18 months until patent law requires publication. Then patents become a part in the knowledge exchange between firms. Thus, managers will select and combine trade secrets, publication and patenting (Holgersson and Wallin 2017; Capponi 2019).

The literature generally does not distinguish between establishing a trade secret and using it. The distinction is essential to understand when trade secrets are used for knowledge exchange, for example, in technology licencing. In some of the literature, in particular, those that follow the methodology of the Oslo Manual on studies of innovation appropriation, the concepts of trade secrets and confidentiality agreements are merged. The latter sets the procedural framework for exchanging trade secrets but does not imply any appropriation or innovative activity as trade secrets or patents do (OECD 2005; OECD/Eurostat 2018) [5].

Searle (2010) study American court cases and finds that trade secret intensity is determined by firm size with a negative relationship, that is not proportional. That is,

[5] The 2018 version of the Oslo Manual has improved how trade secrets and other intellectual property are specified.

trade secrets are more important to SMEs than to larger corporations, but they are important for the large firms as well.

2.2 *Intellectual Property Management and Trade Secrets*

Firms manage trade secrets as part of the processes for intellectual property and innovation management. There are few empirical studies and a lack of theory on how secrecy is used and managed for innovation appropriation (David Hannah et al. 2019; James, Leiblein, and Lu 2013). Even fewer studies consider the role trade secrets have for knowledge flow and search strategies, such as licensing technology in and out of the SMEs. Brunswicker and Vanhaverbeke (2015) for example, discuss how SMEs use external knowledge sourcing and the role of interaction with intellectual property experts, such as patent attorneys. Trade secret management is part of this broader concept of intellectual property management, and concerns how to define, secure and manage control of the immaterial results, that is the knowledge created, from innovation processes. In both Western and Asian firms, the function of intellectual property management and the role of an intellectual property manager is now widespread and accepted as part of creating profit from innovation. Trade secrets and other intellectual property are essential legal and management issues to SMEs. However, few SMEs will have the capacity of a separate intellectual property management function or dedicated resources, as there will be in larger organisations (Carlsson et al. 2008; Al-Aali and Teece 2013; Pisano 2006; Radicic and Pugh 2017; Malach, Robinson, and Radcliffe 2006). In many ways, the management of trade secrets will be less costly and fit better with lean development than the comparable use of patents.

Trade secrets are often used together with other intellectual property rights for the appropriation of all types of innovation: product (including services), process, marketing and organisational innovations. Trade secrets are compared to patents as an alternative for appropriating product or process innovations (S.J. Graham 2004; EUIPO 2017). Most of the literature discuss trade secrets given these two innovations types, but the use of trade secrets is apparent also in marketing innovations (D. Hannah et al. 2014; David R. Hannah, McCarthy, and Kietzmann 2015) and organisational innovations (Liebeskind 1997; Costas and Grey 2016). How trade secrets are used as an innovation appropriation mechanisms and the duality of trade secrets and patents is well described (EUIPO 2017; Crass et al. 2016; S.J. Graham and Hegde 2014; S.J. Graham 2004; James, Leiblein, and Lu 2013; Holgersson and Wallin 2017; B. Hall et al. 2014). Generally, with many deviances, patent applications can be kept as a trade secret for 18 months, before the patent application is published. Firms will thus consider how they will mix the use of trade secrets, patents and other intellectual property rights. Managers reduce risk by having a combination of appropriation mechanisms, even for the same patentable invention. Moreover, innovation managers and executives may find secrecy more important than patents, whereas the legal counsel, may find patents to be more efficient (B. Hall et al. 2014, 419, 385). Thus, studying trade secrets as an appropriation mechanism, cannot be done without considering how it combines with the other mechanisms, the decision mechanisms and the “complementary assets” in the terminology from (Teece 1986). When it comes to risk reduction, trade secrets do not contribute to the owners’ freedom to operate. A key feature of patents is that they, to some extent, contribute to secure the owner’s options to use technology without being hindered by competitors (Holgersson and Wallin 2017). Further, keeping trade secrets depend on human resource management to ensure that the employees contribute to keeping the secret (Hurmelinna-Laukkanen and Puumalainen 2007, 97-98; D. R Hannah and Robertson 2015).

2.3 Trade secret management and SMEs

For SMEs, the use of trade secrets as an appropriation mechanism varies with industry, institutional setting and to what extent they engage in open innovation. SMEs use, as discussed above, more than one appropriation mechanism jointly, in bundles (James, Leiblein, and Lu 2013; David Hannah et al. 2019). There is a tendency for SMEs to use unregistered appropriation mechanisms, often termed “informal”. The previous research usually includes trade secrets in that term (Delerue and Lejeune 2011; Freel and Robson 2016; Leiponen and Byma 2009; Thomä and Zimmermann 2013). The SMEs perceive trade secrets to have fewer formalities and lower costs than patents. As trade secrets must be clearly defined, they function for technology similarly as patents do, for describing the SMEs' intellectual assets and as possible objects for licencing. Trade secrets can both substitute and complement patents (Levine and Sichelman 2018; Capponi 2019; B. Hall et al. 2014). Also, trade secrets are used for non-patentable technology and information. Patents and trade secrets are used in combination – and most patent applications are also trade secrets before they are published.[6] The literature indicates that there are differences in importance between industries and between countries. A recent study by Capponi (2019) points to the temporal dimension: Secrecy is more used in the early phases of innovation. When managers use both mechanisms, patents are the choice for licensing.

Table shows exemplary studies reporting on the percentage of SMEs that use trade secrets or find them important to their innovation. There will be variations from national culture and the type of industry and R&D cooperation (Leiponen and Byma 2009; Delerue and Lejeune 2011). Also, the figures vary depending on the question asked and the selection of respondents.

Table 1

Illustrative Examples of Differences in Approach and Results When Reporting the Use of Trade Secrets by SMEs.

Study	**Percentages and comments**
UK results from the ninth Community Innovation Studies (CIS9) and from UKIPO study (SIPO) (Fassio and Athreye 2018, 13-14)	18% to 23% for SMEs that also use patents 13% for SMEs that did not patent

[6] Patent applications are normally published by the relevant Patent Office 18 months after the first filing. The applicant may ask for earlier publication. If the patent application is only for the USA, an SME may ask for secrecy till grant, however most firms prefer publication before that. (S. Graham and Hegde 2015). (Holgersson and Wallin 2017) propose that freedom to operate and appropriation of complex innovations are better achieved with patents or publications than secrecy.

Finnish innovative SMEs (Leiponen and Byma 2009)	15% of the sample use secrecy, with a negative correlation to patenting
French firms (SMEs and others) using data from the fourth and fifth CIS. Firm size is not significant in the models (Gallié and Legros 2012, 786,790)	35% for intermediate goods 7% in real estate
EU-wide based on CIS2012. Broad question on the effectiveness of secrecy, including non-disclosure agreements. The answers are from innovating firms only (EUIPO 2017, 30-32)	77% in Finland 74% in Germany 43% in the UK 23% in Italy 51% for EU24
Results from the Berkeley Patent Survey in 2008. The figures are for start-ups in the USA (Levine and Sichelman 2018, 35-39)	41% found trade secrets adequate as the sole mechanism for process innovations, 34% for product innovations.

The SMEs may license secrets, in or out, as part of engagement in open innovation. Appropriation is then in the form of information or knowledge that is kept secret. Laursen and Salter (2014, 868-869) paraphrase Arrow's "paradox of information disclosure" and discuss a "paradox of openness". This latter paradox is that the commercialisation of open innovation requires protection. Arrow points to how incomplete appropriability means that the buyer of the information will perform a nonoptimal purchase and allocation (Arrow 1962, 615). Intellectual property that is published, such as patents and design rights mitigates the purchaser's possibility to misappropriate the disclosed information. Trade secrets give no protection if the receiver of the information discloses the information, except the possibility of damages from a court ruling. The seller of the information will use contractual arrangements such as Non-Disclosure Agreements, to mitigate this risk. These arrangements give the seller of the information the possibility to stratify the information disclosed to the seller. Some layers may be in the form of patents or copyrights, whereas others could be trade secrets (Levine and Sichelman 2018, 14). Figure exemplifies this in showing how an SME can combine trade secrets and a patent application.

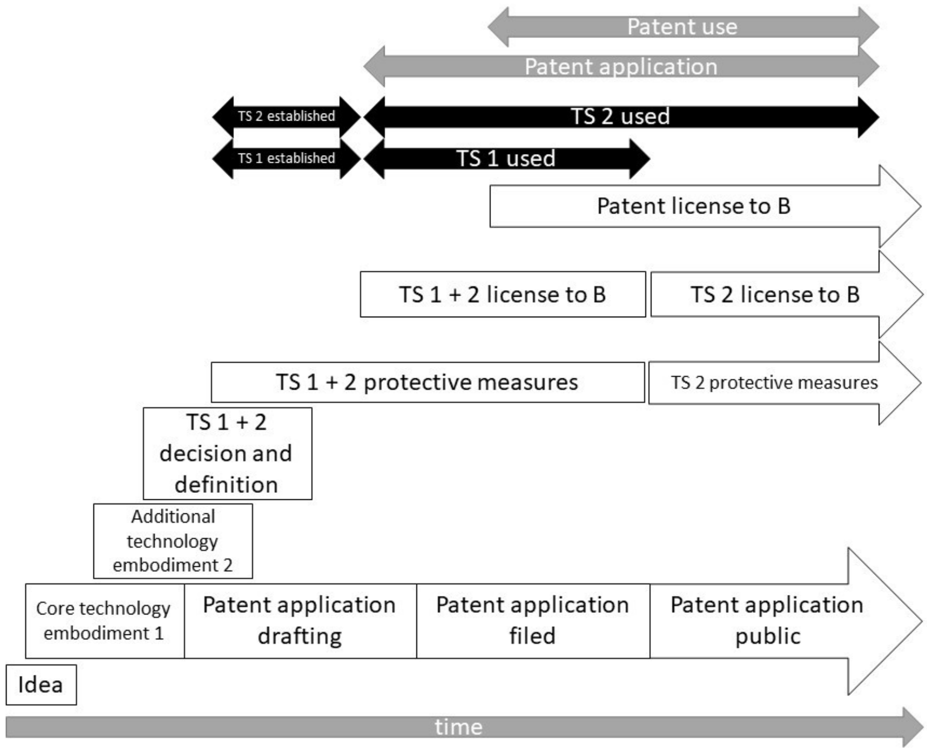
2.4 *Establishing versus using*

The previous literature distinguishes to some extent between the establishment and use of patents, trademarks and designs, but not so for trade secrets. For patents, a common term for intellectual property managers is “apply for”, whereas for trademarks and design registration the term is “register”, as the process usually is more straight forward than for a patent and results in registration within months. A trade secret is not registered but is established when it fulfils the legal criteria: The secret must be defined and not be known or readily available to others, have a commercial value from being secret, and there must be protective measures in place. As for copyright, and different from patents, trademarks and designs, there is no authority that at the point of establishment can confirm that the trade secret fulfils the legal requirements. However, when the responsible manager finds that the trade secret is established, the secret can be kept and possibly used. The main uses of a trade secret are appropriation and licensing. When technological trade secrets are useful for appropriation of innovation, they are often part of the concepts of “lead time advantage” or “complexity”. Trade secrets function to keep competitors from entering the market, and if they do, with an inferior product or service. This lead time advantage, as discussed in (Von Hippel 1982, 109; Hurmelinna-Laukkanen and Puumalainen 2007) is different from the possible larger market share caused by launching a product first, the so-called “first-mover advantage” (Lieberman and Montgomery 1998).

The knowledge that constitutes a trade secret can be licensed because it is defined and protected. A definition of when the trade secret is *used* is when it functions for appropriation or licensing. We illustrate this distinction in Figure .

Figure 1

The Difference Between the Establishment and Use of Trade Secrets (TS), and How Patenting and Trade Secrets Can Be Stratified.



Here an idea is implemented into technology. The technology has a core that we label "1". For this technology, the firm decides to file a patent application. While the technology develops, and the patent application drafting begins, the firm realises that there are additions to the technology that can be kept secret for a long time, labelled "2" in the figure. The firm now describes and limits 1 and 2 and decide to keep them as trade secrets (TS). When they have done so and put protective measures in place, there are two trade secrets established. TS1 is what the later patent application describes, TS2 is a useful addition, such as the temperature range where a process is most efficient. There could be more additions that are commercial trade secrets, such as the results from market tests or business plans. Now firm B gets a license. TS1 and TS2 are now both used. Meanwhile, the firm files a patent application that includes

TS1. B gets a license to the possible patent as well. After 18 months or less if the applicant asks, the patent application is published. Then TS1 is no longer a secret and the use of TS1 ends. However, TS2 is now used as part of the license to B. Further down the timeline; it could be so that TS2 is eventually revealed when the technology is sold in the open market. In that case, the use of TS2 ends, but the use of the patent continues.

The scholarly literature has rarely distinguished between establishing a right and using it (B. Hall et al. 2014, 400). Thus, it is a new approach in surveys when we in our study of SMEs ask both to what extent they established trade secrets, and to what extent they used their trade secrets.

2.5 The research questions

Our research objective is to understand better how SMEs manage trade secrets. With data on the firms from the survey and the tax and accounting data, we can find associations with the characteristics of the firms. As there is a rich literature comparing secrecy and patenting, we found it interesting to compare with data on the SMEs patenting. We thus ask:

> *Research Question 1a - To what extent do SMEs establish, use and find trade secrets of importance,*
>
> *Research Question 1b - and what characterises this establishment and use?*

The SMEs that use trade secrets could be firms without R&D, keeping old secrets or isolating themselves and not engaging in knowledge exchange. SMEs participate in innovation clusters to exchange knowledge and collaborate with others (Uyarra and Ramlogan 2012, 36). Licensing is a mechanism to overcome the paradox that firms engaging in open innovation will have to both share and protect knowledge (Bogers 2011). Licensing is thus an indication of knowledge exchange. There should then be associations between trade secret use and indicators of innovation and collaboration. Our question is:

Research Question 2 - Do the SMEs that use trade secrets engage in knowledge exchange through participation in clusters and licensing?

Management of trade secrets is needed for handling the paradox of openness by layering the information, both when the trade secrets are established and used. SMEs that have documented procedures, and inform their employees about handling trade secrets, will have better trade secret management. Procedures are of essence for establishing a trade secret. When using a trade secret, for example, in licencing, written procedures will mitigate risk.

Research Question 3 - Are there associations between the use or establishment of trade secrets in SMEs and procedures for trade secret management?

3 Data, variables and models

3.1 Samples

We build our study on data from a 2014 survey of 3871 Norwegian firms with between one and 249 employees. Two government agencies, Innovation Norway and the Norwegian Industrial Property Office (NIPO) commissioned the study to understand better how SMEs use intellectual property and what services they need. For the survey, we used a proprietary database of all Norwegian SMEs. We excluded firms without commercial activities and e-mail address. We sent out 61781 questionnaires using e-mail with a link to a web form. The e-mail was addressed to the management, used the registered e-mail address of the company and referred to the government agencies. We explained the background and the purpose of the survey and the different terms used. We received 3871 complete responses. We compared the respondents’ profile with the general profile of Norwegian SMEs for the industry sector, number of employees and region. The deviation is most substantial for respondents in the building and construction industry and micro-firms with less than ten employees. The regional differences were small. We concluded that our data is representative. However, a possible bias is that more firms interested in innovation and intellectual property answered.

Of the 3871 firms in the initial dataset, we found publicly available accounting data from Statistics Norway for 3218 firms for the period 2012 to 2016. The firms we did not find accounting data for are mostly firms with sole proprietorship where reporting of accounting is not mandatory. From the accounting data, we found the revenue and whether the SMEs capitalise R&D results. In accounting, a firm must capitalise research results when it is likely that they will use the research results as an asset; in other words, that the results are turned into innovation. In addition to accounting data, we used publicly available data from the Research Council of Norway (RCN) on an innovation tax incentive scheme where R&D costs give a tax deduction of up to 20 per cent. The tax incentive is only granted after evaluation and approval by the RCN (Benedictow et al. 2018). We used such a grant as a binomial variable that indicates, early-stage R&D with commercial potential.

The survey had 65 questions on intellectual property use and management. We excluded groups of questions if the respondent indicated the topic as irrelevant. The survey form guided the most intellectual property intensive respondents to more detailed questions. Many of these questions were on the management of intellectual property and trade secrets. We gave subsets of 1959 and 831 firms more detailed questions. The 1959 firms were the ones that considered secrecy to be very or somewhat important. They answered questions on what types of secrecy they used. The 831 firms are the ones that would get the most detailed survey, with questions on intellectual property procedures and licensing. We made the selection of these SMEs based on positive answers to questions on management involvement: Top management or board discussions on the freedom to operate and the relevancy of trademarks, patents, design registrations, copyright or trade secrets.

For most overall questions, we thus have answers from 3871 firms, and for the more detailed question, we have from 831 firms. For the results of the regression analyses we have 3218 firms (the ones of the 3871 where we had tax data), and 677 firms (the ones of the 831 when “do not know” is reported as “missing”).

3.2 *Variables*

We use five dependent, binary variables, making one model for each:

> Trade Secret Total: These are all SMEs that report the use of trade secrets (633 SMEs) or that established trade secrets the last five years (215 SMEs) or that had been in conflicts concerning trade secrets. There is an overlap between these two first groups of 48 SMEs.
>
> Trade Secret Established: These are the 215 SMEs that established trade secrets for the last five years. Establishing a trade secret implies defining the secret and protective measures.
>
> Trade Secret Used: These are the 633 SMEs that used trade secrets for the last five years. Use of a trade secret should imply that the secret is licensed or that there are some activities around the secret, such as the launch of a product that embeds the secret.
>
> Secrecy important: This is the broadest group of possible trade secret users. They are the SMEs that respond, “secrecy is important”.
>
> Patent Total: All SMEs that expressed an interest in patenting, by applying, using or being in conflict. We included this variable for comparison with trade secrets. We list the independent in the table below.

Table 2

Independent Variables for the Models Where the Number of Firms Are 3218 and 677.

Independent variable	***Number of firms***	***Type***	***Description***
R&D tax_incentive	*3218*	*Binomial*	*SMEs that were granted tax subsidies (the Norwegian "Skattefunn" statutory subsidy) for one or more R&D projects. Each project is evaluated by the Research Council of Norway. The grant is only for R&D, not for commercialisation.*
R&D_capitalised	*3218*	*Binomial*	*SMEs that capitalised R&D expenses in their annual reporting. The capitalisation indicates that the firms find it more than 50% probable that the R&D will generate a surplus.*
Export	*3218*	*Binomial*	*SMEs that answer they export in the survey.*
Contractual	*3218*	*Binomial*	*SMEs than answer they engaged in NDAs or contractual agreements on trade secrets. †*
Age	*3218*	*Continuous*	*The number of years since the SME was founded as recorded in the Norwegian company register.*
Rural	*3218*	*Binomial*	*SMEs located in an area that qualifies for governmental direct support and tax relieves according to EU/EEA rules.*
Cluster	*3218*	*Binomial*	*SMEs than answer they belong to an innovation cluster specified in the survey.*
Foreign ownership	*3218*	*Binomial*	*SMEs where the majority shareholder or owner is not Norwegian.*
Revenue	*3218*	*Continuous*	*The natural logarithm of the revenue of the SMEs from their public annual reporting.*
Procedure	*677*	*Ordinal*	*The answer to the question "To what degree are the procedures for the management of trade secrets and confidentiality agreements in writing and available to the employees?". Answers are "high", "some" or "low", see Table 5. †*

License out	*677*	*Ordinal*	*The answer to the question "To what degree has the board or the management considered licencing out the firm's own intellectual property to other firms?" Five choices between none and "very high". †*
License in	*677*	*Ordinal*	*The answer to the question "To what degree has the board or the management considered licencing in the firm's own intellectual property to other firms?" Five choices between none and "very high". †.*
Licensing practice	*677*	*Ordinal*	*The answer to the question "To what degree does your firm know how to do the practical parts of licencing, such as negotiations, finalise agreements and follow up the terms?" Five choices between none and "very high". †*
IP in collaborations	*677*	*Ordinal*	*The answer to the question "To what degree does your firm transfer your own Intellectual Property (IP) into cooperative projects with other firms?». Five choices between none and "very high". †*

3.3 *† indicates that the "Do not know" answers are reported as missing*

3.4 *Models*

Our dependent variables are binary. We did regression analyses with probit models using the Stata programme in version 15.1. We built five initial models for "Trade Secret Total". In these models, we tried different combinations of the first five independent variables. We found that the model with all the variables had a similar constant and was consistent for all variables. We then used the same nine variables for the five probit models in Table where the dependent variable is the different versions of secrecy and patents. For the last five independent variables where 677 answers were used in the regression, we used the same dependent variables.

4 Results

4.1 The percentage of SMEs that use trade secrets or secrecy as an appropriation mechanism

The positive answers to the question, “did you establish trade secrets the last five years” is 6 per cent compared to 12 per cent for patents. When we ask the broader question, “did your firm use trade secrets for the last five years”, the figures more than double: 18 per cent used trade secrets, but only 5 per cent used patents. When we asked the general question “Do you find secrecy important for your business”, 21 per cent of the SMEs find secrecy very important.[7] Looking into the combined total use of patents and trade secrets in Table 3, we see that nine per cent of the SMEs are involved in both patents and trade secrets. These figures are substantially lower than other studies indicate in Table 1.

Table 3
Counts for the Combined Involvement of Patents and Trade Secrets.

		Patent Total: 0	1	Sum
Trade Secret Total	0	2.158	269	2.427
	1	562	**305**	867
	Sum	2.720	574	**3.294**

Use both patent and trade secrets: **9.26 %**

[7] Due to limitations on the size of the survey, we did not ask a similar question for the importance of patents or other types of IP.

4.2 Characteristics for the SMEs

In the first four models in Table , we explore if there are differences depending on how broadly we framed the question on trade secrets.

Table 4

Probit Models for Independent Variables with N=3218.

Variables	Trade Secret Total	Trade Secret Established	Trade Secret Used	Secrecy Important	Patent Total
R&D tax incentive	0.46***	0.39***	0.30**	0.36***	0.84***
	0.06	*0.09*	*0.07*	*0.07*	*0.07*
R&D capitalised	0.12*	0.23**	0.02	0.15**	0.33***
	0.07	*0.09*	*0.07*	*0.07*	*0.07*
Export	0.17***	0.27***	0.14**	0.07	0.35***
	0.06	*0.08*	*0.06*	*0.06*	*0.07*
Contractual	0.56***	0.62***	0.45***	0.86***	0.53***
	0.05	*0.09*	*0.06*	*0.06*	*0.07*
Age	0.00**	0.00	-0.01*	0.00	0.00
	0.00	*0.00*	*0.00*	*0.00*	*0.00*
Rural	-0.04	-0.06*	-0.01	-0.04*	-0.09***
	0.02	*0.03*	*0.02*	*0.02*	*0.03*
Cluster	0.26**	0.38***	0.15	0.28**	0.79***
	0.12	*0.14*	*0.12*	*0.12*	*0.12*
Foreign ownership	0.08	0.29*	0.028	0.15	0.57***
	0.12	*0.16*	*0.13*	*0.13*	*0.13*
Revenue	-0.03*	-0.08***	0.00	-0.05***	-0.05**
	0.02	*0.02*	*0.02*	*0.02*	*0.02*
Constant	-0.83***	-1.46***	-1.16***	-0.91***	-1.22***
	0.13	*0.20*	*0.14*	*0.13*	*0.16*
Observations	3.218	3.218	3.218	3.218	3.218

Robust standard errors in *italics*
*** p<0.01, ** p<0.05, * p<0.1

For most of the independent variables, the associations are comparable for the use of patents and the variants of trade secret use. The associations are weaker or less significant for use than for establishment. For the tax incentive and capitalisation of R&D costs, as proxies for innovation in early and late stage, the association is stronger for patents. The association is interesting as the literature describes trade secrets to be of more used as an appropriation mechanism, and we thus expected a stronger association. It is the same pattern for export that literature finds associated with innovation.

The SMEs use of contractual arrangements., concerning secrecy or confidentiality in business relations associates positively in all models. The use of contracts, such as NDAs, does not indicate that knowledge is shared, but they indicate that the SMEs prepare for sharing.

For the age of the SMEs, we find no or a very low association for all models. We had expected that entrepreneurial firms would tend to use trade secrets more than older firms. The small, negative association for trade secrets used, could indicate that young firms depend more on inbound trade secrets that are not combined with patenting. Levine and Sichelman (2018) published results on start-ups' use of trade secrets. From those we believed there could be an association, so that young and entrepreneurial SMEs use more trade secrets. This area is interesting for further qualitative studies on entrepreneurial firms.

We have three variables that concern geography, cooperation in innovation clusters and the possible influence of foreign majority ownership. We see that SMEs that are more centrally located associate more with trade secrets and patents. The apparent association with participation in innovation clusters may indicate that best practice is shared among the members. The robust association between patent use and foreign ownership is fascinating. There is a weakly significant association with establishing trade secrets, and it could indicate that for SMEs foreign owners depend more on intellectual property as risk mitigation when investing, as they may lack other sources of information or control available to national investors.

Finally, looking at the revenue, we had expected from literature that trade secrets were associated with lower revenue and patents with higher. Instead, we find a similar, negative association; however, with the establishment of trade secrets more strongly associated with lower revenue.

Our findings show that SMEs who use trade secrets and patents have similar associations for our dependent variables. The differences between the types of trade secrets are not substantial for these models, but when we next look at the SMEs' use of procedures, the distinction is more relevant.

4.3 Investigating the SMEs' procedures

We asked all the 3871 firms if they had made agreements concerning secrecy or confidentiality in business relations., 49 per cent of the firms had, 49 per cent had not, and 2 per cent did not know. When we asked to what degree (high, some, low), they had procedures for trade secret management, the question is to the core of the SME's ability to use trade secrets for appropriation or information exchange. In order to license a trade secret, the firm needs procedures. In the case of misappropriation, the SMEs may have to demonstrate to a court of law that they have taken measures to keep trade secrets or to follow the agreed terms of confidentiality. Roughly, one-third of the SMEs say such procedures are in place. The figures are in Table 5.

Table 5

To What Degree the SMEs Have Procedures, and If They Are in Writing and Available to the Employees.

Questions	Number of SMEs	Low	Some	High	Do Not Know
For all SMEs in the survey: To what degree do you have procedures for documentation of secrets and records of the employees that are given such information?	3871	58%	17%	22%	3%
For SMEs where the board or top management are involved in intellectual property management: To what degree are the procedures for management of trade secrets and confidentiality agreements in writing and available to the employees?	831	38%	25%	33%	4%

The last question is the selection criteria in the regression models we made for the subset of SMEs with top management attention to intellectual property management. The results from the probit regression are in Table 6. There are 677 observations from the 831 firms as we used data only from the firms with tax data available.

Table 6

Probit Models for the Use of Procedures Related to Licensing and Collaborations.

Variables	**Trade Secret Total**	**Trade Secret Established**	**Trade Secret Used**	**Secrecy Important**	**Patent Total**
Procedures	0.09***	0.15***	0.03	0.14***	0.09*
	0.05	*0.06*	*0.05*	*0.05*	*0.05*
License out	0.09*	0.06	0.05	0.10**	0.20***
	0.05	*0.06*	*0.05*	*0.05*	*0.05*
License in	0.01	-0.07	0.07	0.08	-0.07
	0.06	*0.06*	*0.05*	*0.05*	*0.06*
Licensing practice	0.14**	0.24***	0.01	0.06	0.23***
	0.05	*0.07*	*0.06*	*0.06*	*0.06*
IP in collaborations	0.19***	0.20***	0.09**	0.07	0.08*
	0.05	*0.06*	*0.05*	*0.05*	*0.05*
Constant	-1.32***	-2.73***	-0.98***	-1.41***	-1.52***
	0.19	*0.25*	*0.18*	*0.19*	*0.19*
Observations	677	677	677	677	677

Standard errors in *italics*
*** p<0.01, ** p<0.05, * p<0.1

Formalisation and communication of trade secret management procedures in SMEs associate with their establishment of trade secrets. The association is stronger than for patents: For patents, the innovation system creates procedures to follow, whereas for establishing trade secrets, the firm's procedures are of the essence. The degree of licencing out associates with the patents but not with the establishment or use of trade secrets and indicates that the SMEs do not use trade secrets as the object of a license. For licensing in we do not have significant results. Both the use of patents and the establishment of trade secrets associate at a comparable level with the needed practical knowledge for licensing. The SMEs confirm that they have procedures and understanding of the licensing process, also for trade secrets.

The establishment of trade secrets associates stronger than the use of the patent system does, with bringing the intellectual property into cooperative projects. The association is interesting, indicating that the SMEs do establish trade secrets if they enter into collaborations. In practice, they may then either formalise the trade secrets internally and not share them, or they may enter into more informal agreements that keep the knowledge secret but not in the form of licensing. For further research on how SMEs use trade secrets at this detailed level, qualitative studies are needed.

5 Discussion and Directions for Further Research

5.1 *Summarised Answers to the Research Questions*

In Research Question 1a, we asked about the extent of the SMEs establishment and use of trade secrets. We found more detailed figures, lower than in most previous studies. In Research Question 1b we asked for the characteristics that expand on the difference between establishment and use. For the nine variables in Table , we found similar associations for secrecy and trade secrets as for patents. In Table 6 the data is from the SMEs where top management is involved in intellectual property issues. Here the firms that have established trade secrets have a stronger association with the formalisation and availability of procedures. The formalisation is in line with and confirms the concept of bureaucratic secrecy appropriation mechanisms described by David Hannah et al. (2019), that is management-initiated procedures for keeping trade secrets as opposed to employee-initiated norms. Another observation is the lack of strong associations with licensing, but clear associations with the transfer of intellectual property into collaborations. Such transfer implies both licencing in and out but in a collaborative setting. A possible implication is that the SMEs may prefer to license trade secrets within collaborations rather than as part of a general licencing of technology.

For Research Question 2, we do not have a significant association for engagement in licensing. However, both use and establishment of trade secrets are associated with collaborations. This difference indicates that the SMEs use patents for licencing out technology, rather than trade secrets. However, as answer to Research Question 3, the SMEs' management procedures associate with trade secret establishment. Here is an opportunity for innovation managers: With procedures in place, the new legislation in the EU and USA contribute to a risk reduction in the case of misappropriation by collaboration party. Then it should be more attractive to use trade secrets, to include trade secrets in licensing deals, and thus engage in open innovation.

5.2 The Problems of Setting a Baseline

Policymakers may need a baseline to see if the new legislation influence SMEs management of trade secrets. A baseline is not easily set. With our study, we find that the number of SMEs using trade secrets are in line with the recent results that Fassio and Athreye (2018, 13-14) found, in the range of 13 per cent to 23 per cent. A distinction is that we found that only 6 per cent established trade secrets. For patents, it is opposite. On average 12 per cent applied, but only 5 per cent used them. Because many patent applications are not granted, we expected that more SMEs apply for patents than use them. For trade secrets, the increasing rate is not apparent. For example (Mansfield 1985) shows that trade secrets in average leak within 12 to 18 months. In that case, the number of trade secrets may not build up in a firm. The firms could, however, believe that they have a secret, even if it has leaked. Also, our question does not distinguish between trade secrets that are created by the firm and those that are licensed in. We find that 49 percent of the firms engage in contractual agreements that facilitate the exchange of secrets. When firms share a secret, it will count on the "use of trade secret" for both, but only for one of them as a "created trade secret". The more companies in our study that exchange information in the form of secrets, the higher should this difference be.

In summary, there is no clear baseline for the impact of the new legislation on SMEs. However, if the legislation has a positive influence on SMEs' management of trade secrets, the associations to licensing should become apparent in future studies. Thus, we suggest that future studies should research associations between licensing and use of trade secrets, rather than reporting percentages.

5.3 Implications for theorising

As we discussed, there is no accepted theory concerning the management of trade secrets. From the perspective of economics and innovation studies, our contribution is a more detailed view of how SMEs manage and use trade secrets. We demonstrate empirically how the concepts of establishment and use of trade secrets are different, as we illustrate in Figure .

We show how there are associations between SMEs' use and establishment of trade secrets for indicators of early-stage (the R&D tax_incentive variable) and for later stages of innovation (the R&D_capitalised variable). We find an association between export and the use of trade secrets. Love and Roper (2015) points to export being strongly associated with innovation and growth. Surprisingly, we do not find clear associations for licensing. Instead, the associations are strong for collaborative innovation and in clusters. The associations confirm that trade secrets have a role both for SMEs' appropriation of innovation and for their sharing of knowledge. Our findings suggest that SMEs share trade secrets more under the framework of contractual agreements, such as NDAs than under license agreements. We confirm the concurrent use of patents and trade secrets by SMEs, but at a firm level and thus not for the same innovation; we do not know if the responding SME has more than one innovation. As most patent applications are trade secrets for the first 18 months of patent prosecution, there is no surprise. The surprises are in the different use of patents and trade secrets in licencing and the association with clusters and participation in collaborations.

5.4 *Implications for policymakers*

Our study gives more details and lower percentages than for example the study from the European Commission (2013c). We confirm quantitatively with more details than previous studies, the assumed associations between the use of trade secrets for SMEs and their engagement in knowledge exchange, innovation clusters and open innovation. Our study finds no association between licensing and trade secrets. An explanation could be that the lack of a legal framework has impeded such licensing. With the continuing legal harmonisation in both the EU and the USA, we expect increased licensing of trade secrets, that may benefit SMEs, open innovation and the flow of knowledge.

5.5 *Implications for management in SMEs*

From the framework of "profiting from innovation" by Teece (2006), an assumption is that better management of intellectual property, that includes management of trade secrets, implies more profit from innovation. We show that the firms that establish trade secrets tend to have procedures in place and participate in collaborations and innovation clusters. That there is no association between licensing and establishing trade secrets, points to an area that could be explored by managers. As the legal systems harmonise, the framework for licencing trade secrets improve. There are systematic reviews of the legal systems in different countries, that may facilitate the exchange of knowledge in the form of trade secrets (M.F Schultz and Lippoldt 2018; EUIPO 2018; Caenegem 2014). The most critical implication for managers is however that trade secrets should no longer be regarded as an "informal" innovation appropriation mechanism, but as a mechanism that associates with procedures and co-exists with patents and other intellectual property. Our distinction between establishing and using a trade secret comes from management practice, as exemplified in Figure . Our results confirm that the distinction is empirically meaningful. Thus, a manger that foresees trade secrets as an essential tool for controlling innovation and engaging in open innovation should consider supporting procedures to avoid loss of secrecy and misappropriation. In addition, procedures that enables sharing of the knowledge in collaborations and open innovation, in particular in the form of licensing, seem to be a practise that can evolve.

5.6 Shortcomings and Directions for Further Research

Our data comprise many SMEs of all industrial sectors, but from a single country and based on one survey. As discussed, there are national differences, thus future studies should include more nationalities. We framed the question in a novel way with the distinction of establishment, use and importance, but we cannot be sure that the respondents understood the differences. Due to the terms of the survey, we could not contact the firms and complement the survey with in-depth interviews. Future studies should add qualitative methods, learn more about the differentiation we point out and how managers combine trade secrets with other intellectual property. Literature indicates that there are differences between industries, and there are also likely differences in management approach. David Hannah (2005) show that procedures have a positive effect - and how “carrot”, such as trust, is a better approach than “stick”, such as employee agreements perceived as threatening. Robertson, Hannah, and Lautsch (2015) elaborate further on the managerial aspects. They discuss how to create a positive secrecy climate. David Hannah et al. (2019) introduce how there can be normative procedures established without management. The even broader view from Costas and Grey (2014) is that secrecy is a normal part of organisational life. Our survey questions did not build on this research and thus did not investigate managerial practices, types of innovation and forms of organisation. SMEs’ will always have secrecy as an indispensable component of innovation and business. The relationship between trade secrets and other innovation appropriation mechanisms is complicated. We have provided new insight and distinctions. However, more effort is needed to understand how SMEs better can manage trade secrets to form competitive advantages and to participate in knowledge exchange and open innovation.

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Research paper 5:

Teaching Trade Secret Management with Threshold Concepts

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Teaching Trade Secret Management with Threshold Concepts

Abstract

Trade secret management is an emerging field of research. Teaching trade secret management includes several challenging topics, such as how firms use secrets in open innovation. The threshold concepts framework is an educational lens well suited for teaching subjects that are transformative and troublesome. We identify four such areas in trade secret management and discuss how threshold concepts can be a useful framework for teaching. We then present an outline of a curriculum suited for master's programmes and training of IP managers. Our main contribution is to management and educational sciences. The study also concerns innovation studies and jurisprudence.

Keywords: Appropriation mechanisms, intellectual property management, threshold concepts, trade secret management, trade secrets

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1 Introduction

Trade secrets are used in open innovation. When we teach how to manage trade secrets, this contrast between secrecy and openness seem like a paradox. Trade secrets are secrets with commercial value that are delimited and managed. The secrets become mechanisms for appropriation and control of innovation. As part of intellectual property (IP) management, trade secret management builds on the views of management science, economics, innovation studies, knowledge management and jurisprudence, with additions from sociology and organisational psychology. As for most topics in management science, research must be cross-functional and interdisciplinary, because the IP managers have a diverse background and function in their organisations. There is limited research on trade secret management, and no research on how to teach.

Teaching the topic of trade secret management builds on the learners having previous understanding of IP and IP management at an advanced level. Our experience stems from teaching students at master's programmes at European universities, as well as courses for intellectual property managers and other managers of innovation in research, development and business operations. For all these groups, we experience that some of the topics in the curriculum need special attention because they are not only complicated and challenging, but counterintuitive. From this starting point we discuss if the educational principles of the threshold concepts framework could be a possible lens to use in the teaching of trade secrets (Flanagan 2019). We investigate how the threshold concepts framework could be a way of understanding the characteristics of trade secrets. This way could change the understanding of the nature of trade secrets, their management, and how this understanding has consequences as to how to teach. We start this paper by reviewing several challenging and complicated issues in trade secrets management teaching to identify if they are counterintuitive. We use counterintuitivity as an indication of, and as a point of entry to a clearly challenging topic, because when teaching we can observe confusion. We see that the learners do not understand. In our paper, we then develop the discussion of these counterintuitive issues and compare them with the characteristics of threshold concepts.

Threshold concepts are increasingly regarded and applied as a framework for teaching challenging issues. There are an increasing number of empirical studies on how, or whether, learning improves when teachers present a topic as a threshold concept; and thresholds concepts are now considered among the high impact pedagogies (Nicola-Richmond et al. 2018). Our paper is conceptual and explorative from the point of educational sciences and the teaching of intellectual property in management and innovation studies — however, the challenges in teaching trade secret management stem from secrecy being complicated and human. (Bok 1989 Ch.II p.13) discuss how control over secrecy and openness is needed to protect a person's identity, plans, actions and property. Such protection need is similar for a legal person such as a firm or an organisation, where trade secrets are a common form of secrecy.

Our research goal is to substantiate threshold concepts as a framework for teaching trade secret management, and to exemplify this with a curriculum outline. The first sections introduce trade secret management and a proposed list of challenging issues. We then give examples and identify possible threshold concepts. We then apply the threshold concepts in outlining a curriculum on trade secrets in a typical IP management course, before we conclude with recommendations for further research.

2 Trade secrets and IP management

"*Every IPR starts with a secret***.**[1] *Writers do not disclose the plot they are working on (a future copyright), car makers do not circulate the first sketches of a new model (a future design), companies do not reveal the preliminary results of their technological*

[1] Intellectual Property Right – the intellectual property defined in terms of the right, such as a patent or a trademark.

experiments (a future patent), companies hold on to the information relating to the launch of a new branded product (a future trade mark), etc. In legal terminology, information that is kept confidential in order to preserve competitive gains is referred to as "trade secrets", "undisclosed information", "business confidential information" or "secret know-how". Business and academia sometimes use other name tags for it such as "proprietary know-how" or "proprietary technology"." (European Commission 2013a, 2)

This quote is from the explanatory memorandum of the EU directive on trade secrets. The context is the EU's strategy of creating an "Innovation Union" by 2020 and the importance of harmonisation of trade secret legalisation for innovation. The quote shows the lack of a harmonised vocabulary, in that six different terms are listed, and the title of the proposal has three different terms "trade secrets", "undisclosed know-how" and "undisclosed business information". There is a total of eight overlapping terms within the two first pages of the proposal.

The term "trade secret" has a clear legal definition in the EU and the USA, from the legislative work we discuss below (M.F Schultz and Lippoldt 2018). The definition does not mean that the language used by business managers and researchers become clearer, as the many terms above remain in use for a reason. As we discuss later, trade secrets are more of a process than just being a commercial opposite of openness. Vague terms that include the explanatory "undisclosed" or "proprietary" and the broad "information" or "know-how" serve a purpose in that they encompass information that may or may not become trade secrets as well as the well-defined trade secret. The word "secret" has itself negative connotations (Bok 1989 Chap. 1, p 12). For a researcher that needs to keep a trade secret, it can be better to talk about "proprietary technology" and thus avoid a conflict with the Mertonian norm of communality. For a business manager or lawyer drafting a non-disclosure agreement "business confidential information" may sound more relevant.

Most legal definitions of “trade secret” include four concepts:

i) it is business-related technical or commercial information

ii) it must not be known to the public

iii) it must have value for business from being kept secret, and

iv) there must be a reasonable effort to protect the trade secret from disclosure.

In 2016 an EU directive was final (European Commission 2016) and it is now adapted in national legislation. The USA has had a similar process of legal harmonisation with the Uniform Trade Secrets Act (UTSA), followed by the Economic Espionage Act (EEA) and the Defend Trade Secrets Act (DTSA) of 2016. These laws together with international trade agreements build a legal framework for trade secrets viewed as intellectual property. Japan and China have also recently updated their legislation. The perspective in these laws is unfair competition. They now provide the trade secret holder with improved measures in the case of misappropriation. Also, the laws extend the scope of trade secrets to all commercial information. It is an integral part of the teaching to explain and discuss the impact the different terms and jurisdictions have on practical trade secret management. This part of the curriculum is complicated, but not challenging in terms of being incoherent or counterintuitive: The different legislations are all national variants of the Paris convention’s more than hundred years old rules on the principle of unfair competition (Bodenhausen 1968).[2]

3 Exceptions from trade secret legislation

There are areas where secret information is not protected by trade secret laws. An important issue is to explain and discuss these exceptions in view of ethics and societal needs. Our examples are from the EU directive, but whistle-blowers are for example

[2] The Paris Convention is the oldest international agreement on intellectual property, originally from 1884. In 1900 a revision introduces article 10bis on unfair competition. Trade secret misappropriation has always been regarded as one such form of unfair competition. Others include passing-off and counterfeit. Later trade agreements, including the Trade-Related Aspects of Intellectual Property Rights (TRIPs) are more detailed on trade secrets.

also protected under the US laws (Levine and Seaman 2018; Menell 2017) and in many other countries (Right2INFO.org 2019).

Investigative journalism:

Journalists in the EU cannot be hindered by trade secrets legislation to investigate and publish news on companies' practices and business affairs**.** The EU directive only concerns unlawful conduct by which someone acquires or discloses, without authorisation and through illicit means, information with commercial value. Further, the companies must treat the information as confidential in order to keep a competitive advantage over their competitors.

Legal obligations to disclose information of public interest:

The EU Directive does not alter the legal obligations on companies to disclose information for such public policy objectives. In these matters, the public interest prevails over private interest. Companies are subject to legal obligations to disclose information of public interest, for example, in the chemical and pharmaceutical sectors. The regulations, which ensure a high level of transparency, are not be affected. The EU Directive does not provide any grounds for companies to hide information that they are obliged to submit to regulatory authorities or to the public

The rights of citizens to access documents in the possession of public authorities:

Moreover, the EU Directive on Trade Secrets does not alter and does not have any impact on the regulations that foresee the right of citizens to access documents in the possession of public authorities, including documents submitted by third parties such as companies and business organisations.

Revealing misconduct, wrongdoing or illegal activity:

In addition, the EU Directive expressly safeguards those who, acting in the public interest, disclose a trade secret for the purpose of revealing a misconduct, wrongdoing or illegal activity. This safeguard is operative if the trade secret was acquired or passed to the whistle-blower using illicit means such as the breach of law or contract.

For an organisation, the management must understand when information they would like to keep a secret can be trade secrets. If employees are told that trade secrecy applies to information discussed above, where ethical considerations should lead to publication, then the ability to identify, keep and manage the real trade secrets may suffer.

4 Trade secret management

Trade secrets are secrets with a causal relationship to a firm's competitive advantages. Business managers finds that trade secrets are more important for controlling innovation, than are patents, copyright and trademarks (Levin et al. 1987; Cohen, Nelson, and Walsh 2000; Arundel 2001; Leiponen and Byma 2009; Gallié and Legros 2012; B. Hall et al. 2014; Eurostat 2016). The laws constitute a framework for knowledge transfer, such as licensing, in the form of trade secrets. The legal framework may be of use to the holder of a trade secret in the case of misappropriation: If the secret is stolen, or it becomes public by breach of contract or trust. We will say no more about the legal side of trade secrets because secrecy is not defined by law. For other intellectual property such as patents and copyright, jurisprudence defines the concept; there are no patents without patent law. For trade secrets, however, the laws are mere fall-backs in the case of unsuccessful management. What matters is how the managers of trade secrets teach and train the organisation to keep the secrets; how the secrets are used for sharing knowledge within an organisation and with third parties, and how the secrets are combined with other measures, such as patents and copyright, to create and maintain competitive advantages. In this view, the difference between secrets in general and trade secrets is simply that trade secrets are managed with a commercial purpose.

Large organisations may organise trade secret management as part of intellectual property management. In other organisations, the management of trade secrets may be part of roles like innovation managers or R&D managers or be integrated into legal or human resources management or be termed as knowledge management. An important role is also that of managing information security, often called cybersecurity. The management tasks can be divided into phases, such as definition of the trade secret, installing the protective measures, exploitation and loss of the secret (Granstrand 2000, 26; Lezzi, Lazoi, and Corallo 2018; Holgersson and Wallin 2017; Al-Aali and Teece 2013; Li and Tsai 2009; Bos, Broekhuizen, and de Faria 2015).

Trade secrets are mostly handled in and between organisations. Secrets are a normal part of organisational knowledge management. Whenever they may give competitive advantages, the organisations tend to build procedures and rules for management. The procedures and rules are either initiated by management, or by the employees themselves. The employees will be burdened with keeping the secrets, and may bend those rules instead of breaking them, adapting to situations not fully catered for in the rules (Costas and Grey 2014; Grey and Costas 2016; Marx and Muschert 2009; Robertson, Hannah, and Lautsch 2015; D. R Hannah and Robertson 2015; David Hannah et al. 2019). Trade secrets are often used in combination with other mechanisms for controlling competitive advantages in innovation. To encompass both IP including trade secrets and other mechanisms, such as contractual agreements, researchers in innovation studies use "appropriation mechanisms" as a general term (Gallié and Legros 2012; B. Hall et al. 2014). The complexity of trade secrets being an organisational phenomenon, and being combined with other mechanisms, creates a need for a different approach to teaching than for intellectual property management in general. We now turn briefly to complexity before we discuss threshold concepts.

5 Simultaneities in trade secret management teaching

(Davis 2008) introduces the term "simultaneity" to describe certain phenomena in education. The term is derived from complexity theory and is used in education sciences for "events and phenomena that exist or operate at the same time". Simultaneities oppose the ideas of binaries, dichotomies and hierarchies. Simultaneities will be perceived as counterintuitive to learners: Phenomena that are seemingly separated are presented both as a unity and as co-occurring. An example of simultaneity is the “knower and knowledge” where curriculum reflects the knowledge and pedagogy the knower. They coincide, interdependent yet independent, but remains separated. In trade secret management teaching simultaneities exist on a fundamental level in that openness and secrecy can be applied as characteristics of the same information. (Hilgartner 2012) discuss an “dialectic of revelation and concealment” in an historical example from the Human Genome Projects. The researchers from competing organisations in the example discuss trade secrets and future research directions, intricately balancing openness and secrecy. We illustrate another practical simultaneity in Figure .

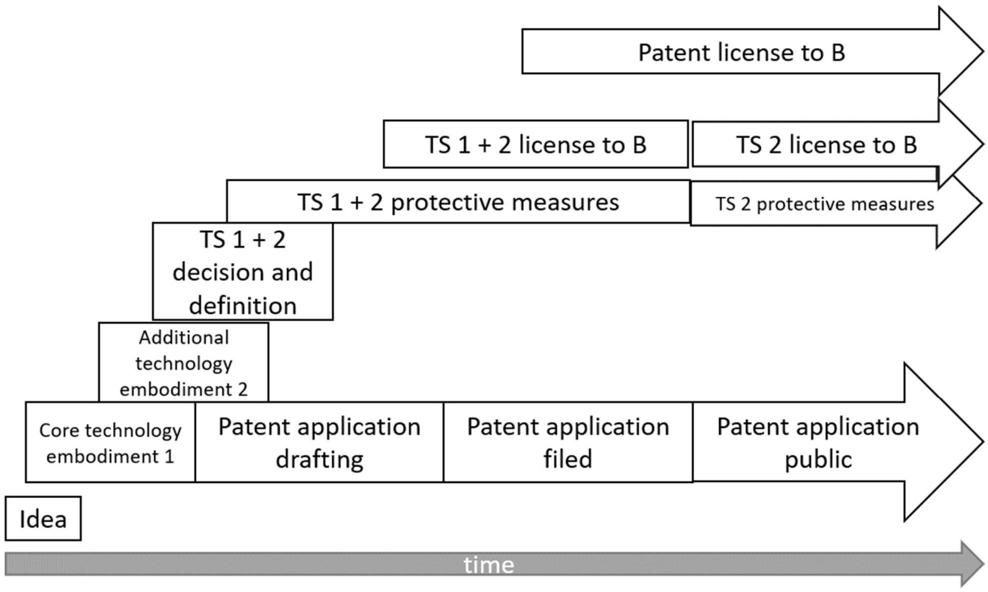

Figure 2 Combinations of trade secrets and patents – it is not either-or. For clarity copyright and trademark use is not shown.

Here an idea is implemented into technology. The technology has a crucial part, a core, that we label “1”. The firm then files a patent application. The technology develops, and while the patent application drafting starts, the firm understands that there are other technology parts that may be kept secret over a long time, labelled “2” in the figure. The firm now describes 1 and 2 and keeps them as trade secrets (TS). When they have done so and put protective measures in place, there are two trade secrets. 1 is what the later patent application describes, 2 is a useful addition, such as the temperature range where a process is most efficient. There could be more additions that are commercial trade secrets, such as the results from market tests or business plans. There could also be trademarks, copyrights and other appropriation mechanisms involved, that we do not show in the figure. Now firm B gets a license. TS1 and TS2 are then both used. Meanwhile, the firm files a patent application that includes TS1. B gets a license to the possible patent as well. The patent application is eventually published. Then TS1 is no longer a secret and the use of TS 1 ends. However, TS2 is now used as part of the license to B.

In this case, we use boxes and illustrate as if TS1, TS2, the patent application and the granted patent and the three licenses are different concepts. However, an educational view may be to present these as a simultaneity. It is hindsight to present the complete picture as we do. For the IP manager, the versions of the secrets and patent applications evolve together. We can separate them. Different people and organisations and managers will be involved along the timeline, but at any point in time trade secrets and patents will blend. There is no dichotomy.

6 Experience-based issues that are challenging to teach

We made a list of trade secret related issues that we find challenging to teach, both at universities and in workshops with professionals such as IP managers, Chief Technology Officers or corporate lawyers. For some of the issues, the challenges are complicated rules, different legal systems or arbitrary logic. However, we realised that for some issues the challenge is their counterintuitivity. As an example, there is a paradox in that secrets can be used to share knowledge. As a private experience, we have all shared secrets. However, then the context is the secret itself and a personal matter. However, the borderline between private secrets, privacy issues and trade secrets blend. An example is how clinical data from genetic testing is included in proprietary databases. In other words, the unique DNA of person becomes part of a firm's trade secrets. This information can then be shared between firms (Cook-Deegan et al. 2012). There are both ethical controversies and sequence of transactions that create a counterintuitive situation. In a context of innovation or research, secrecy is often regarded as limiting the flow of knowledge and not as an enabler of sharing. Even in the clear case of licensing of technology that includes trade secrets, the sharing of knowledge is not discussed beyond the agreed non-disclosure. In economics "spillover effects" are recognised, but then often as a case of misappropriation of trade secrets due to workforce mobility (Delerue and Lejeune 2010). The effect that trade secrets, as patents also do, solve the Arrow information paradox[3] and are included in the paradox of openness[4] illustrates how the use of secrets is counterintuitive in that they are involved in two paradoxes concerning innovation (Laursen and Salter 2014; Bogers 2011; Arrow 1962).

We propose a two-step process to identify first counterintuitive issues, and second, from these identify possible threshold concepts. Methodologically, we draw upon the process of identifying such bottleneck elements in learning material on the decoding-the-disciplines approach and backcasting (J. Robinson 2003; Middendorf and Pace 2004; Shopkow 2010).[5]

In Table 7, we list a selection of challenging issues and indicate possible counterintuitivity, to initiate a mapping of the terrain. More details are in the Appendix – Detailed table of challenging issues with an indication of counterintuitivity. The examples in the appendix discuss the distinction between complicated and counterintuitive issues. We chose counterintuitive issues as a point of entry to initiate further analysis, as these issues are, in our experience challenging to teach. Later, in

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[3] Arrow shows how the prospective buyer of a technology wants to know how it works before paying. If the buyers then learn the technology, they do not need to pay for the knowledge they just got. If the seller has a patent, or there is legislation on trade secret misappropriation, the paradox is mediated.

[4] Laursen and Salter paraphrases Arrow in that "the creation of innovations often requires openness, but the commercialization of innovations requires protection". Such protection may include trade secrets.

[5] Backcasting is opposed to forecasting: To design a desirable future and then find policies and programs that connect to the present. See also the brief discussion on a curriculum later in the article.

Table 8 we show the characteristics of threshold concepts before we compare those to the counterintuitive issues in Table 9.

Issues	***Counter-intuitive***
Patent applications may be kept secret for 18 months, and there are complicated rules.	No
Trade secret legislation borders to laws on business conduct, whistle-blowing and privacy.	No
A trade secret has a value. It has an impact on accounting and taxation.	No
Trade secret management depends on recording metadata for trade secrets. The metadata can be public.	Yes
Workforce mobility cause conflicts on trade secrets.	No
Trade secrets can be used for sharing and exchanging knowledge, and as part of open innovation.	Yes
Trade secrets cannot be managed as other IP as the property is lost if published, however, trade secrets are mixed and managed with another IP	Yes
Secrecy and openness are not legal concepts, such as other IP. They are formed in a process, and there is no rigid dichotomy.	Yes
The terms of a non-disclosure agreement (NDA) must be managed.	No
The scope of a trade secret is not possible to validate unless it is litigated.	No
Trade secret management includes cybersecurity.	No
There is confidential information that is not trade secrets.	No
Negative knowledge (negative know-how) can be a trade secret	Maybe
An organisation can have procedures for handling secrecy that is set by management or that the employees create without management involvement.	No

Table 7 Examples of challenging issues with an indication of counterintuitivity.

7 Threshold concepts

As illustrated above, the nature of trade secrets, seen from a teaching and learning perspective, represents to the learners and novices in the discipline a fluid and less distinct landscape. Also, among academics, there is a limited or unclear agreement regarding teaching in this field as to what graduates should know. There is a lack of bright points of navigation, clear or predefined goals for the learners, and there is a lack of clear ontologies and fixed epistemologies. In sum, the teaching of trade secret management is quite challenging.

More so than in many other epistemological fields, the understanding of trade secrets and their management is dependent upon developing a way of thinking and developing a sense of understanding of 'the underlying game' or 'episteme'. That is, to develop 'habits of the mind' (Perkins 2005; Shulman 2005).

The threshold concept framework is a pedagogical framework that focuses on the aspects of a field or a discipline that at face value seems counterintuitive and troublesome, and yet the understanding of these aspects is essential to the understanding and mastering of that discipline. These aspects or concepts in the discipline may be seen as a portal, and passing it, leads to a transformed understanding of the subject matter (J. Meyer and Land 2006; J.H. Meyer and Land 2005; J. Meyer and Land 2003; Land et al. 2005). Early research in the field stems from economics, where the underlying barriers to the students understanding are linked to the understanding of 'opportunity cost'. This barrier is perceived as one such essential threshold into the understanding of economic theory (Shanahan and Meyer 2006). In this research, the focus is upon identifying and describing an educational core or points of gravitation in a field, with the purpose of contributing to an integrated understanding of the field.

The table below illustrates what might be the characteristics of a threshold concept.

Characteristics	***Comment***
Transformative	changes the way in which the student views the discipline
Troublesome	e.g. when it is counter-intuitive, alien or seemingly incoherent
Irreversible	difficult to unlearn
Integrative	bring together different aspects of the subject that previously did not appear, to the student, to be related
Bounded	delineate a particular conceptual space, serving a specific and limited purpose
Discursive	incorporate an enhanced and extended use of language
Reconstitutive	may entail a shift in learner subjectivity, which is implied through the transformative and discursive aspects already noted. Such reconstitution is, perhaps, more likely to be recognised initially by others, and also to take place over time
Liminality	mastery of a threshold concept often involves messy journeys back, forth and across conceptual terrain

Table 8 Characteristics of threshold concepts, adapted from (Flanagan 2019).

Together these characteristics describe the highly complex nature of a threshold concept. Note that there are an internal relationship and interdependency among them. For example, a threshold concept such as “trade secrets can be used in open innovation”, see

Table 9 below, will at the same time be transformative and discursive, since a new perspective of reading the world will include a new way of describing what you see.

Table 9 below shows the four issues we find counterintuitive when teaching. For these we have briefly commented on the characteristics of threshold concepts from Table 8.

Issues	**Main threshold concepts characteristics and comments**
Trade secret management depends on recording metadata for trade secrets. The metadata can be public.	*Transformative:* Trade secrets can be part of an IP portfolio and discussed with others that are not in the know, including IP managers. *Troublesome:* It is counterintuitive that the attributes of the secret are not secret. *Irreversible:* A trade secret has attributes and metadata. *Integrative:* It is the fundament for appropriating knowledge with a mix of IP that includes trade secrets.
Trade secrets can be used for sharing and exchanging knowledge, and as part of open innovation.	*Transformative*: Trade secrets are part of the knowledge flow between firms. *Troublesome:* There is no contradiction between open innovation and trade secrets. *Discursive:* Changes the view of licensing. *Reconstitutive:* The starting point for questioning academic and industrial norms. Also, to see how secrecy and openness balance.
Trade secrets cannot be managed as other IP as the property is lost if published, however, trade secrets are mixed and managed with another IP	*Transformative:* Changes the view of the early phase of innovation projects. *Troublesome:* The other types of IP changes, when trade secrets are an integral part of their cycle. *Integrative:* The different types of IP are integrated by trade secret initiation. *Liminality:* The details of national and international patent, copyright, trademark and design law, as well as marketing law, must be known before trade secrets can be mixed and managed.

Secrecy and openness are not legal concepts, such as other IP. They are formed in a process, and there is no rigid dichotomy.	*Transformative:* Other IP only exist as legal concepts. The literature mostly presents trade secret management as legal management. *Troublesome:* Opposed to registered IP and copyright, successful management of secrecy depends on human factors. Openness may lead to a need for secrecy, for example, in the case of biobanks and privacy issues. *Integrative:* The early-stage innovation process comprises decisions on the joint use of different types of IP. *Discursive:* The ability to switch between a perspective of openness and secrecy, and of legal and organisation concepts.

Table 9 Challenging issues compared to threshold concepts characteristics

In Table 9, four issues have at least four of the eight characteristics of threshold concepts. All include not only the counterintuitivity of the "troublesome" characteristics, but they are also transformative. For teaching trade secret management, we then have essential issues that we find changes how the student views the discipline. A problem will then be to formulate these as learning objectives together with the other, non-troublesome issues. We discuss that in the following clause on a curriculum.

The lack of clarity as to learning objectives, that is precise goals or aims to be learnt, will position the learner in a state of liminality (Land, Rattray, and Vivian 2014; Turner 1969; Gennep 1960). Liminality, a term derived from social anthropology, describes the period of leaving one kind of state or understanding, but has not yet arrived in a new state, or reached a new understanding. This state is characterised by uncertainty and ambiguity for the learner, and it is for the individual in an anthropological sense space from which to move out. Many learners perceive their learning trajectory in the same way – as a relatively linear and directed path to mastery. To this field, the understanding and management of trade secrets, liminality or uncertainty should be perceived as a space for sharing, affordances and opportunities.

8 The epistemological landscape.

In the above, we have described how trade secrets and the teaching thereof is an ambiguous and complex discipline, and how the threshold concepts framework may be used as a lens to describe and analyse. To further explore the teaching of trade secrets, we now turn to how this field need to be understood in epistemological terms. Describing a knowledge domain and how this may be taught and learnt, also require an understanding of the epistemological characteristics of that domain. Learners, even at master level, tend to want simple ontologies, fixed epistemologies and recipes as to how to achieve the desired learning outcomes. This attitude is enforced by current exam systems. However, to be a participant in a given field, teachers and learners need to develop an expanded understanding of what constitutes knowledge in that field. We draw upon three sources of epistemological framing; Polanyi's ideas of 'tacit knowledge', Gibbons' distinction between Mode 1 and Mode 2 knowledge and Schön's seminal work describing the reflective practitioner (Gibbons 1994; Schön 1987, 1983; Polanyi 1966).

The knowledge perspective adopted to frame trade secrets and the teaching thereof rests on what Gibbons has termed Mode 2 knowledge (Gibbons 1994). Gibbons distinguish between Mode 1 and Mode 2 knowledge development. Whereas Mode 1 represents traditional knowledge, reflecting the classic academic hierarchies, Mode 2 knowledge is developed in an interaction between different actors from science and industry. Typically, this kind of knowledge is developed out of a defined problem or a given context, often a "wicked" one. Consequently, the knowledge is interdisciplinary and relies on both theoretical and practical input.

Furthermore, tacit knowledge plays an important part. Tacit knowledge in an organisation rests in the experiences, the relations and the networks among a group of people. This kind of knowledge is rarely written, or otherwise formalised, but can be activated and shared when the need arises. It is consequently hard to get access to for newcomers in an organisation, but the participation in communities socialises members towards a way of thinking. This also means that tacit knowledge is not easily taught or acquired and may emerge through dialogue and participation. Mode 2 knowledge is more connected to its immediate application, and the interplay between development and application. In a real sense, learning, also seen as an organisational endeavour, is not separated from the development of knowledge and its application. Although the individual and social aspects are present in all types of learning and knowledge production, to Gibbons the individual drive is seen as the dominant in Mode 1 knowledge production, and the social or collective drive is seen as dominant in Mode 2 knowledge production (Gibbons 1994). To the learners and practitioners alike the process of achieving knowledge in the domain is associated with the state of liminality and recognising emergent ontologies and epistemologies. In earlier work, Schön has elaborated on these abilities of the practitioner, and describes the development of such emergent knowledge as a "reflective conversation with the materials of a situation", aligned with elements of improvisation, moving in "indeterminate zones of practice" (Schön 1987).

9 An example curriculum on trade secret management in a typical IP management course

In Table 10 we present an example curriculum building on (Land et al. 2005; Hunkins and Hammill 1994). We have placed the four threshold concepts within progress from the legal definition to how to improve the organisation. An alternative way of presenting the curriculum could be to start by introducing secrecy as a human and organisational concept. The threshold concepts would then follow. This approach could be better suited for skilled IP managers. For students we find that they often lack an understanding of intellectual property, and thus legal definitions and practical examples are needed before the threshold concepts can be meaningful. In a course on trade secrets for IP managers, an objective is to rapidly change their perception of trade secrets and how to manage them. Their starting point is that they know IP and thus also trade secrets, and that they cannot use much time on the course. Early introduction of the discipline specific threshold concepts will then incite learning the details. For the student on a master level course, the general concepts of IP can be taught together with trade secret management. The pace will be slower, and there will be more time for reflection.

Topic	*Content*
Motivation	Changes – legal, tax, employee mobility, cloud computing, cybercriminals, open innovation, trade wars; secrecy as part of human nature; differences in attitude in academia and industry.
Definition of trade secrets	The legal definition in EU and European countries, the USA, China and Japan. There are many sources from work on the new legislation.
Practical examples of the definition	What are "not public", how much value must the secret have, what measures must be taken, what are the exemptions, ethical and societal considerations.
Examples of practice areas where trade secrets differ from other IP	Both technical and commercial information, no registration, no fees, cannot be published, the secret need not be static – it can change, no time limits, no requirements for documentation.
Threshold concept: Metadata	Starting to explain metadata and how it can be used to delimit and document the secret. Use examples, let the students fill in metadata. Discuss how the metadata may be public.
Trade secrets are a subset of confidential information	Using privacy and personnel records as an example.
Compare patents and trade secrets	Examples, on patent applications being secret and prior use rights
Compare copyright and trade secrets	Examples, on software, open-source and database rights
Famous examples - discussion	For example: are Coca Cola, and WD40 formulas trade secrets? Employee mobility and cybercrime.
Exploring examples	Negative information, inventions that cannot be patented, big data, client data Using recent litigation as cases

Threshold concept: Trade secrets are managed differently but mixed with other IP	Building on the discussions and examples. Use research collaborations as an example: Secrecy must be secured from the beginning if it is needed in commercialisation of technology. May be needed as an object for licensing
Licensing needs an object to license	Discuss trade secrets in licencing and how it is combined with other IP
Threshold concept: Trade secrets in knowledge exchange, and as part of open innovation.	Lift the discussion to open innovation and knowledge flow in society and how trade secret legislation facilitates that. Then use licensing as practical examples. Show agreements.
Introduce the valuation of trade secrets	The value must be understood when licensing and exchanging information. Discuss accounting standards and tax issues.
Introduce the role of the employee and the procedures in an organisation.	Discuss how confidentiality is handled (trade secrets and, e.g. privacy – coming back to trade secrets being a subset.
Threshold concept: It is not the legal definition that matters, but to keep the confidential information and stay out of courts. There is no dichotomy but a process.	Using the role of the employee and project teams to move over to organisational issues. If secrets are successfully kept, there is no need to distinguish between the variants. The secrets are flexible over time. Documentation is risk management.
Cybercriminals are only interested in trade secrets – not other IP	Other IP is usually public, so protection is from the legal system
The roles of individuals, teams, organisation and states	Secrecy as a natural part of work life. Lifting the discussion to procedures and innovation systems. Coming back to exemptions, ethics and flow of knowledge in society.
Introduce steps to improve the organisation	Education, governance and policy, processes in place, IP portfolio management including trade secrets with metadata

Table 10 An example curriculum with threshold concepts

10 Conclusion

We demonstrate that four central issues in the teaching of trade secret management can be viewed through the lens of threshold concepts, and thus be used to open the field to the learners. We then show how these concepts may be used in an example curriculum.

We contribute to theorising in that we link the lack of ontological clarity to the simultaneities, and thus also to how trade secret management integrates with IP management. We relate this understanding to the epistemological concepts of tacit knowledge, Mode 2 knowledge and the reflective practitioner.

We explained IP management and trade secret management as a practitioners' skill, and thus, we provided an example curriculum aimed at the education of management practitioners. However, this contribution is not only related to management and educational sciences but has relevance for innovation studies. Trade secrets are part of the broader concept of appropriation mechanism. For researchers of innovation and jurisprudence it is crucial to better understand the ontological shift from trade secrets for keeping knowledge secluded, to trade secrets used for knowledge transfer in open innovation. There is then no dichotomy of openness and secrecy. There is a process of knowledge appropriation where well-defined trade secrets blend with other mechanisms.

11 Limitations and future research

The present study is conceptual. We build our proposals for using threshold concepts in trade secret management education on limited experience. Two of the authors have long experience in teaching IP management, but mainly in the Nordic countries and the United Kingdom. We know from the literature that there are cultural differences in how secrecy is used for innovation (Delerue and Lejeune 2011; Serradell-Lopez and Cavaller 2009). There are also, as discussed earlier in this paper, legal differences. With the new EU and US legislation, these regions have moved towards regarding trade secrets more as property, whereas Japanese and Chinese legislation see the issue as a question of fair competition. The cultural differences may have an impact on what issues are considered as counterintuitive. The impact of cultural differences when teaching trade secret management is an exciting possibility for future research.

In our experience, there seem to be a male bias in the attendance of both academic and industrial courses on IP management. (Delerue and Hamid 2015) find no gender differences in the ethical attitude to trade secret misappropriation. However, there are reported gender differences in the attitude to secrecy among adolescents (Frijns et al. 2005). These studies may be a starting point for research on gender differences relevant for the teaching of trade secret management.

In Table 7, we refer to normative literature on the issue of trade secrets in open innovation. There are differences in the approach to trade secrets between fields of industry, as well as between academic institutions and firms. One example from the ICT industry is in (Feldman 2006) that empirically examine if trade secret law affects high-tech employees' willingness to keep confidential information. In a life sciences study researchers that cooperated with industry expectedly reported more trade secret results from their research (Blumenthal et al. 1996). The effects of industrial sponsorship on researcher are discussed by (Czarnitzki, Grimpe, and Pellens 2015). We have not tested the four threshold concepts we identify in courses for differences in learning outcome versus the industrial or academic background of the learners (Flanagan et al. 2014). To identify such differences is an interesting question for further research.

We started the discussion on trade secrets by pointing at the lack of ontological clarity. We then explored the epistemological landscape and connected to the discussion on Mode 2 knowledge. When knowledge production is collaborative, the management of trade secrets must adapt, and this is an area for more research (Ankrah and Al-Tabbaa 2015). As management of trade secrets develops, so must also its teaching. The framework of threshold concepts may improve the teaching of trade secret management.

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13 Appendix – Detailed table of challenging issues with an indication of counterintuitivity.

ISSUES	COUNTER-INTUITIVE	COMMENTS, EXAMPLES	REFERENCE
Patent applications may be kept secret for 18 months, and there are complicated rules.	No	Patent applications follow national, regional and WIPO rules. The US allows publication by inventor one year before application, and secrecy for national only applications till grant. After 18 months, the application and all prosecution are public. The choice of 18 months is regarded as practical and builds on bureaucratic needs from the last century.[6]	(S.J. Graham, Marco, and Miller 2015; Franzoni and Scellato 2010)
Trade secret legislation borders to laws on business conduct, whistle-blowing and privacy.	No	In China trade secret law is based on business conduct law. Privacy, for example, in medical records, is not trade secrets but could be in the case of bio-banks.	(Caenegem 2014; Lippoldt and Schultz 2014)

[6] The 18 months publication of patent applications come from the needs of the Dutch Patent Office in the 1960ies. Patents were published at grant and the Dutch Patent Office had a huge backlog. Nobody outside the Patent Office but the patent applicant knew that a technology would be patented. This secrecy could last for many years and wrongful investments could be made by third parties. The Dutch then began to publish all applications after 18 months of secrecy. The West-Germans and then the world followed, see (Davidson 1969; Hoffmann 1972)

A trade secret has a value. It has an impact on accounting and taxation.	No	The value of a trade secret can be estimated in a similar way as for patents, e.g. from net present value of a royalty stream or the cost to develop the similar product or service – or misappropriate the competitor's trade secret.	(T. Fischer and Leidinger 2014; Lagrost et al. 2010)
Trade secret management depends on recording metadata for trade secrets. The metadata can be public.	Yes	A secret starts as information that is concealed. The metadata (such as the field of technology or commerce, the ones in the know, the importance, the associated IP) about the secret and its concealment may be shared without telling the secret. Thus, the manager of trade secrets does not need to know the secrets.	(Li and Tsai 2009)
Workforce mobility cause conflicts on trade secrets.	No	Employees know trade secrets and bring them to a new employer. It is difficult not to disclose a secret in the long run. Some also disclose secrets from anger with previous employer, by negligence or by solicitation from the new employer. The society wants workforce mobility to encourage knowledge flow and improve the efficiency of the market.	(Delerue and Lejeune 2010)

Trade secrets can be used for sharing and exchanging knowledge, and as part of open innovation.	Yes	When firms license technology, the associated knowledge is often in the form of trade secrets. An argument against secrecy is that it is normatively wrong, as all secrecy hinder the flow of knowledge. There is no paradox in trade secrets used in open innovation, as “open” does not mean “published”. For open-source, the norms are collaborative development and shared rights – and thus no trade secrets when published. During development it is possible.	Empirical: (Lippoldt and Schultz 2014) Metastudy: (Perkmann et al. 2013) Normative: (Merton 1973; West and Gallagher 2006)
Trade secrets cannot be managed as other IP as the property is lost if published, however, trade secrets are mixed and managed with another IP	Yes	That property can be lost by disclosure is counterintuitive – and one of the reasons that jurisprudence struggles with including trade secrets in the IP concept. Trade secrets need different management; however, they are managed as an integrated part of IP. The effect is that IP management must be based on the management of secrecy.	(B. Hall et al. 2014; Hurmelinna-Laukkanen and Puumalainen 2007), but do not conclude on the management issues.

Secrecy and openness are not legal concepts, such as other IP. They are formed in a process, and there is no rigid dichotomy.	Yes	All other IP are legal constructs, but trade secrets may exist and be used without any involvement of law. The transition from secret to trade secret is a process that involves risk reduction and documentation of metadata	(Bok 1989; David Hannah et al. 2019)
The terms of a non-disclosure agreement (NDA) must be managed.	No	NDAs are complicated with detailed terms that must be followed. The purpose may depend on the legal system of the jurisdiction, for example, there are differences between common and civil law.	(Wetter et al. 2017)
The scope of a trade secret is not possible to validate unless it is litigated.	No	As for copyright, the circumstances must be compared with the legal definition by a court of law. The scope of the law is set to balance copying with incentives for innovation and use of the patent system. An example is whether there were proper measures against disclosure or not.	(Ottoz and Cugno 2011)
Trade secret management includes cybersecurity.	No	Both the technology of the IT platform and the users may have weaknesses that lead to the loss of trade secrets. Corporate espionage is commonplace. Cybercriminals are only interested in trade secrets (not public, has value).	(Lezzi, Lazoi, and Corallo 2018; Villasenor 2015; Rowe 2016)

There is confidential information that is not trade secrets.	No	Make Venn-diagrams of different terms. Privacy issues and employee records are typical examples.	(Bok 1989; Marx 2016; Weinberg et al. 2015)
Negative knowledge (negative know-how) can be a trade secret	Maybe	If a firm does 1000 experiments that fail, and one that works, an employee leaving for a new workplace cannot use the basis of the 1000 failed experiments to find another workable solution. If explained as "negative knowledge" only, it sounds counterintuitive. If the view is the "sweat of brow", the performed work, it is easier and is similar to why a database is protected in the US.	(Castellaneta, Conti, and Kacperczyk 2017; Junge 2016)
An organisation can have procedures for handling secrecy that is set by management or that the employees create without management involvement.	No	Given organisational psychology and how psychological contracts develop, it is not surprising and easy to explain that rules develop among groups of employees.	(David Hannah et al. 2019; Therese E. Sverdrup and Schei 2015)

--- The end of the thesis ---