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The Economics of Innovation and IP: Empirical Essays from Belgium

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By

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Daar de proefschriften in de reeks van de Faculteit Economie en Bedrijfswetenschappen het persoonlijk werk zijn van hun auteurs, zijn alleen deze laatsten daarvoor verantwoordelijk.

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General Introduction

"As soon as quality competition and sales effort are admitted into the sacred precincts of theory, the price variable is ousted from its dominant position. However, it is still competition within a rigid pattern of invariant conditions, methods of production and forms of industrial organization in particular, that practically monopolizes attention. But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization (the largest-scale unit of control for instance)—competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives."

(Schumpeter, 1944)

Since Schumpeter, economists in the field of industrial organization have had an interest in innovation. One large stream in the literature focused on how market concentration influences Research and Development (R&D) and innovation incentives. The existence of such a direct causal link has been found not to be uncontestable. Scholars proposed that in explaining (inter-industry) variation in R&D incentives, looking at differences in 'technological opportunities' (cfr. Scherer, 1982a; Scherer 1982b) and 'appropriability conditions' (cfr. Arrow, 1962) is of prime importance (Levin et al., 1985). As such, the continuity of a firm's added value will crucially depend on their own innovations, the emergence of competing imitations and next generation inventions.

This thesis bundles three essays in the field of economics of innovation and Intellectual Property (IP) and studies how firms act in order to appropriate the returns to their investments

in R&D and innovation. I study three pathways by which companies can shape the degree of appropriation of their R&D and innovation investments: preempting competition by building up a lead time advantage *(chapter 1),* taking out patents (*chapter 2),* litigating (*chapter 3).*

The renewed empirical lens – combing patent and firm level survey data

By looking at the facts through a new modern empirical lens I contribute to the ongoing debate on incentives for R&D and innovation. Already since long, scholars have used a range of administrative and survey data sources in order to investigate questions related to innovation, R&D and Intellectual Property (IP), be it at an individual, firm or economy level of analysis. The earliest use of patent data for economic research goes back to Schmookler (1966). He conducted his analysis mainly at the industry level by making a concordance between patent subclasses and Standard Industrial Classifications (SICs). Later on, Sherer (1982) linked patent data to other industry level information. Pakes & Griliches (1984), matched patent counts to Compustat Firms but except for the match itself only used patent data in the analysis. An analysis based on a combination of firm level data with variables constructed from patent level databases was seldomly carried out so far (Some notable exceptions are Griliches, 1981; Pakes & Griliches, 1984; Jaffe, 1986 using an NBER dataset (as described in Bound et al., 1982)). At the start of the current century, mainly due to the increases in data availability and processing capacity, the field recognized the opportunity to combine the available array of data at the level of the firm in order to answer its questions using a more integrative approach. Mairesse and Mohnen (2002) stated that combining detailed innovation survey data with other administrative sources would be an important route for future work:

"To make progress in future work, besides gaining experience in using innovation surveys and improving them, it will be important to be able to match the specific information they provide with the usual current accounts, balance sheets, and stock market data, as well as with complementary data from other sources such as on patents and R&D."

Studies taking up the given advice started to appear soon after. Duguet & McGarvie (2005) investigated how well patent citation data measure knowledge flows by merging and comparing firm level data from the Community Innovation Survey with patent data from the European Patent Office (EPO). The results of their study qualify patent citations as useful measures of flows of new technology.

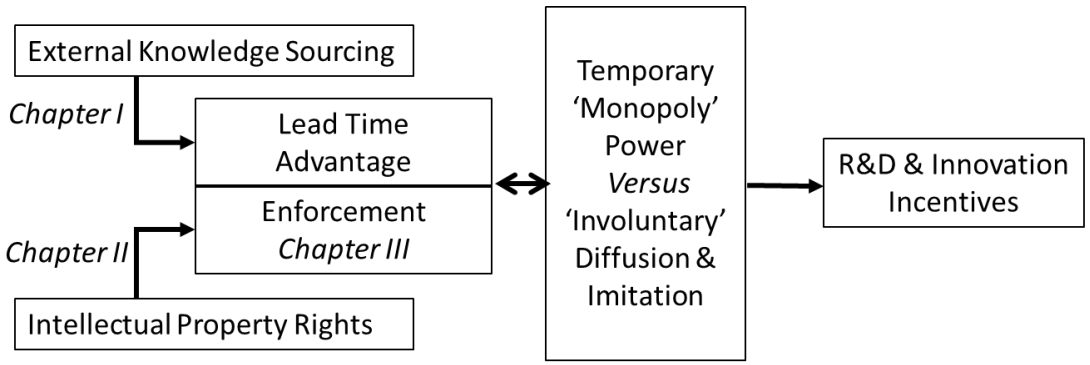
More recently, when investigating questions in the field of the economics of innovation and IP at the firm level using survey data, it has become a best practice to consider complementary measures constructed from administrative patent data (cfr. e.g. Czarnitzki & Toole, 2011; Czarnitzki & Lopez-Bento, 2013; Capelli et al. 2013; Czarnitzki & Delanote, 2015; Leten et al., 2016; Hottenrott et al., 2016; Hussinger et al. 2018). In light of this recent trend, in this thesis, I will empirically revisit three economically important aspects surrounding the appropriation of innovation, namely preempting competition, taking out patents and litigating, using a combination of innovation survey and administrative - patent - data.

Short overview of the Chapters in this thesis

The effect of openness on a firms' ability to seize 'technological opportunities' has recently caught a lot of attention in the open innovation literature (Chesbrough, 2003). As such, the *first chapter* of this thesis examines how external knowledge acquisition could facilitate the

seizing of technological opportunities and influence 'appropriability conditions' by speeding-up the innovation process. The effect of filing patents on innovation is also of contemporaneous importance but has recently been the subject of controversy (Boldrine & Levin, 2013), and is therefore required to be re-examined. Therefore, the *second chapter* investigates to which extent firms that are implementing their acquired knowledge into innovative solutions might get hit by adverse events, such as imitation and (involuntary) diffusion of knowledge, and to which extent patents do or do not alleviate the issue. IP enforcement and litigation can be considered as another alternative way to enable or maintain appropriability of innovations. Given the recent rise in IP litigation cases (Bessen & Meurer, 2005) and the relative lack of contemporaneous firm level evidence on the matter, in the *third chapter* I examine the determinants of IP litigation as at the firm level where I focus on firms' market value at stake in their disputes.

Thesis Layout



Chapter I investigates whether time-to-market considerations could be an alternative to patents for firms to better appropriate the returns of their R&D investments. Being able to out-innovate competition in terms of time-to-market might put firms into an advantageous situation. Mechanisms to achieve such an advantage can mainly be found in the open innovation literature. In particular, external knowledge sourcing may be used systematically to achieve an

effective lead-time advantage over rivals' products. I assess the matter based on a combination of firm level Community Innovation Survey (CIS) and patent application data.

Chapter II explores whether patents function as intended by policy by re-visiting the seminal framework on knowledge leakage by Mansfield. Theoretically, patents should provide protection from imitation. In return for a temporary monopoly on the protected invention, the patentee forgoes on secrecy by disclosing the functionality of the invention to the public in the patent document. I assess the protection function and the dissemination function of patents based on a combination of survey and patent data in an integrated approach.

Chapter III contributes to the economic literature on patent litigation by taking a new perspective. In the past, scholars mostly focused on specific litigation cases at the patent level and related technological characteristics of the invention to the event of litigation. However, from a firm level perspective, observing the economic reality of IP disputes suggests that not only technological characteristics may trigger litigation suits, but also the market positions of the firms. Consequently, this chapter examines the occurrence of IP litigation cases in Belgian firms using the 2013 Community Innovation Survey with supplemental information on IP litigation and patent portfolios.

Chapter I

External information sourcing and time-based innovation[1]

Abstract

Investigating the link between the popular external knowledge sourcing and speed of innovation is of increasing importance. In particular, external knowledge sourcing may be used systematically to achieve an effective lead-time advantage over rivals' products. In this paper, I study, based on firm level Community Innovation Survey (CIS) data, how the effectiveness of using lead time advantages as a means of appropriation is influenced by the openness of the innovation process in general and the external knowledge sourcing strategy more specific. I find that firms with a closed development process, i.e. indicating they developed their innovations or imitations without involvement of external parties, are having a harder time to profit from lead time advantages. Firms directing their external knowledge sourcing strategy towards consumers, suppliers, and science are benefiting from more effective appropriation by means of lead time advantages. The effects of drawing information from competitors and consultants are insignificant. Furthermore, I find diminishing positive returns to the efficiency of using lead time advantage for appropriation from both breadth and depth of the external knowledge sourcing strategy. The diminishing of the returns seems to be mitigated for companies with higher absorptive capacity as reflected in the intensity of their intramural R&D spending.

[1] This chapter is single authored and under further preparation.

I. INTRODUCTION

Although some inventions were come across haphazardly by a lone inventor, the canonical story of the lone genius inventor is largely, as Lemley (2012) puts it, a myth: *"…Edison didn't invent the lightbulb; he found a bamboo fiber that worked better as a filament in the lightbulb developed by Sawyer and Man, who in turn built on lighting work done by others…"* (also see Hargadon, 2003; Hargadon & Sutton, 1997; Singh & Fleming, 2010). Over the course of history, information sources became more widely available and also knowledge sharing between partnering firms, universities, and customers became custom practice. Indeed, to bypass the constraints of own internal knowledge, firms are (increasingly) drawing upon external knowledge (Penrose, 1959; Teece, 1986; Barney, 1991; Grant, 1996). The perception that innovation is a network activity is not a new one. Efficient uptake and management of information have long been considered a prime attribute of successful innovators (Rothwell et al., 1974; Rothwell, 1977, 1992). More recent contributions argue that companies are increasingly sourcing knowledge from outside the firm to complement their own knowledge base and increasingly use external pathways to commercialization to monetize on innovation (cfr. e.g. Chesbrough, 2003). One way to capture value from innovation is to build up lead time advantages and become a first mover with regard to innovation or a deliberate late mover, i.e. an imitator (see Lieberman & Montgomery, 1988, for a literature review on the topic). I define lead time, in correspondence with the literature (see Cankurtaran et al., 2013), as the inverse of speed. Techniques to speed up production and innovation consistently originated in the east before being adopted in the west. At least since the 1980s when Japanese products challenged existing world markets, it is well-known amongst scholars and practitioners that lead time advantages are a crucial factor in competition. As a reason for the success of Japanese manufacturing companies in the 1980, typically the nowadays well-known business strategies

such as just-in-time production and flexible manufacturing are quoted. In the literature less attention has been paid to time-based innovation. It has been argued that Japanese companies followed an innovation strategy which involved updating products in small steps but much more frequently than existing rivals (see Stalk, jr., 1988). Today China is the new champion of accelerated innovation, leveraging concurrent engineering techniques to gain a time to market advantage for non-breakthrough innovations (Williamson & Yin, 2014). Considering this trend but without delving into the international aspects of the matter I aim to investigate lead time based competition in innovation in relation to the external knowledge sourcing strategies of firms. Consequently, this paper argues that certain innovation strategies might be conducive for achieving an effective lead time advantage with respect to innovation. In particular, external knowledge sourcing may be systematically used to promote information-enabled innovation (Reeves et al. 2017) and increase innovation speed to achieve an effective lead time advantage over rivals' product cycles. A recent report by McKinsey & Company already ranked 'capturing external ideas' among the top innovation management practices that differentiates the most from the least agile companies (Bazigos et al., 2015). In their meta-analysis, Cankurtaran et al. (2013), find that development speed is associated with increased new product success. Moreover, they also find in their analysis of the antecedents of development speed that integration with external partners, i.e. customers, suppliers and others, is positively contributing. If firms are indeed benefiting from a speedy development process, it is of prime importance to delve deeper into external information sourcing as an antecedent given the recent growing importance of knowledge and information in an economy of networked firms. I aim to fill this gap by using firm level Community Innovation Survey (CIS) data to answer the questions surrounding *which external information sourcing strategies are most frequently observed to coincide with the build-up of lead time advantages*. As such, this research is closely

related to the literature linking the use of external knowledge sources to innovation outcomes (e.g. Laursen & Salter, 2006; Frenz & Ietto-Gillies, 2008; Leiponen & Helfat, 2010)**.**

I find that firms with a closed innovation process, i.e. firms indicating they developed their innovations or imitations without involvement of external parties, are having a harder time to gain lead time advantages. Firms drawing information from consumers, suppliers, and science are more likely to gain lead time advantages. The effects of drawing information from competitors and consultants are insignificant. The returns to breadth and depth of external sourcing are diminishing in nature. Moreover, for depth I find that there exists an inflection point where returns get negative. Managers should be informed that effective lead time advantages can seemingly be created through diverse and deep knowledge sourcing, although returns are diminishing and with regard for depth returns even become negative after a certain point. Furthermore, collaboration for innovation also seems to correlate with having an effective lead time advantage. My results are in line with prior studies on the topic and suggest that lead time advantage is a robust measure of innovative performance.

The rest of this paper is structured as follows: Section II summarizes the relevant literature and develops the hypotheses. Section III describes the empirical setup. A description of the data and variables used is given and the estimation method is briefly explained. Section IV summarizes the results from a regression analysis before they are subsequently discussed in section V. Section VI concludes.

II. RELATED LITERATURE AND HYPTHESES DEVELOPMENT

New products or processes are the result of applying knowledge and knowhow to a specific need. The process is iterative as innovations get obsolete and new needs emerge. Or as

Hidalgo (2015) puts it in his book *"Why information grows"*, the knowledge economy is a system in which people *"accumulate knowledge and knowhow to create packets of physical order, or products, that augment our capacity to accumulate more knowledge and, in turn, more information".* Moreover, in a networked economy, it becomes increasingly important to source knowledge not only from own experience but also externally. Early movers regarding innovation can thus be considered as those firms (or individuals) that are able to outperform their competitors in applying knowledge to satisfy customer needs.

Accordingly, in this paper, I am interested in exploring the mechanisms a company can utilize to influence the degree to which it profits from lead time advantages in innovation. In what follows I will consider three main levers: 1) external knowledge sourcing breadth and depth, 2) use of specific external knowledge sources, 3) opening up the product development process. The next paragraphs of this section summarize how these 3 mechanisms relate to the current state-of-the-art.

Mathematical sampling models of innovation (Nelson, 1961; Evenson & Kislev, 1976; Baldwin and Clark, 2006) regard the innovation process as draws from a technological opportunity distribution which results in particular innovation outcomes. Leiponen & Helfat (2010) relate these models to the use of (external) information sources. They argue that the chance of obtaining a favourable draw increases with the breadth of knowledge sourcing as an additional information source represents an extra draw from the distribution. The greater the number of draws is, the more likely one of them will exceed a certain critical value for success. I argue that if one of the outcome dimensions of the opportunity distribution is timeliness, a greater number of draws will also contribute to the chances a company exceeds the critical value with regard to time and has the opportunity to be the early mover.

II.A. Knowledge Sourcing Breadth and Depth

Our research is closely related to the literature linking the use of external knowledge sources to innovation outcomes (e.g. Laursen & Salter, 2006; Frenz & Ietto-Gillies, 2008; Leiponen & Helfat, 2010). The empirical evidence points to companies with more and deeper external knowledge sources are having a better innovative performance. Laursen and Salter (2006) find that searching widely and deeply is curvilinearly related to innovative performance. Franz and Ietto-Gillies (2008) find that while own-generation, and bought-in R&D matter in innovation performance, the benefits of joint innovation efforts in the form of cooperation are less clear. And according to Leiponen and Helfat (2010), broader horizons with respect to innovation objectives and knowledge sources are associated with successful innovation. These studies do, however, not, or only in an indirect way, take into account one crucial dimension of successful innovation, i.e. timing.

Timely innovation in an environment of shortening product lifecycles required companies introduce flexible systems to meet continuously evolving customer needs (see Tolio & Urgo, 2013 for an example of a flexible system). Moreover, industrial sectors started applying unified models to support the speed-up of the innovation process, e.g. TRIZ (Russian acronym for 'theory of inventive problem solving') in mechanical engineering or RAD (rapid application development) in software development. From an economical perspective these systems and models are supportive to achieve a lead time through innovation. Chesbrough (2017) argues that managing the impact of open innovation on internal innovation is one of the main future challenges of open innovation, mentioning that bringing in external knowledge into the organization could potentially slow down the innovation process if a company has not invested adequately in capacity to process the influx.

Koput's model of innovative search (1997) states, amongst other things, that within firms there may exist an 'attention allocation problem', i.e. only few ideas are given the required attention to bring them into implementation. In this respect, the attention-based theory of the firm (see also Simon, 1947 and Ocasio, 1997) argued that in allocating managerial attention to certain activities, firms are limited by their available attention pool. According to the theory, decision-makers need to 'concentrate their energy, effort and mindfulness on a limited number of issues' in order to achieve sustained strategic performance (Ocasio, 1997: p. 203).

While benefits of ever broader search might be diminishing in nature, because of limited additional usefulness of certain sources. Scanning a new source requires spending relatively little attention and finding an new interesting piece of knowledge can contribute to the quality of an innovation but also to the timeliness with which it can be introduced. Therefore I hypothesize:

H1: The relationship between the broadness of knowledge sourcing and the degree to which companies can profit from lead time advantage is positive but with diminishing marginal returns.

For deep search 'over searching' would tap into attention pool to a greater extent. External search that tries to explore too many sources deeply could lead to a misallocation of the limit pool of attention that is available, which could lead to innovations that are of inferior interest to the market or it could delay the process of getting a useful invention to market. Therefore I hypothesise:

H2: The relationship between the deepness of knowledge sourcing and the degree to which companies can profit from lead time advantage is positive but with diminishing marginal returns, eventually leading to negative returns (inverted-U).

II.B. Specific Sources of External Information

The Yale survey (see e.g. Klevorick et al., 1995) in the US and the PACE survey (see e.g. Arundel, 2001) in Europe have documented a wide range of external information sources used by companies to complement their own knowledge base. These include: suppliers, clients, competitors in the same industry, consultants, and university and government research. These information sources can be divided into two broad categories: horizontally or vertically related. I define horizontal and vertical relations reasonably close to the definitions in the mergers and acquisitions literature (see e.g. Salinger, 1989). Vertically related sources pertaining to institutions either upstream (suppliers) or downstream (clients) to the company. Horizontally related sources pertaining to institutions having similar product offerings (competitors). I regard information from government and university research as vertically related as it likely is positioned upstream with regard to the innovation process of private companies. I regard information from consultants as horizontally related as it concerns information that is equally available amongst competitors and is not stemming from either up- or downstream entities in the value chain. For horizontally sourced information there is a trade-off taking place: i.e. more and better information could put firms at a speed-advantage, however insofar as information is disseminated multilateral, the advantage might be mitigated because then competition is then also better informed. Vertically sourced information however, I hypothesize, typically abide a logic of the more, the better, since the information stemming from them is acquired on the basis of an idiosyncratic relation with the up- or downstream entity and therefore does not entail direct information spillover to competition.

H3: External information sourcing from institutions that are vertically related to the focal company, i.e. suppliers, clients and science positively contribute to the degree to which the focal company profits from lead time advantages.

II.C. Co-operation for Product Development

While companies can purposely use a certain external knowledge sourcing strategy, they also still have to decide on how to operationalize the innovation process. First, the company faces a make-or-buy decision (Veugelers and Cassiman, 1999). Second, if a company decides to 'make', the question arises of whether they will innovate in relative isolation or would rather co-innovate with others (as in e.g. Bossink, 2002). Proponents of open innovation argue extensively that an open innovation process contributes to the likelihood of innovation success (e.g. Chesbrough, 2003, 2017). I argue that an important dimension of a successful outcome is timeliness. Therefore, in line, I hypothesize:

H4: Companies that co-develop their product innovations profit to a higher degree from lead time in innovation.

III. EMPIRICAL SETUP

The data set used to conduct the analysis originates from the Flemish Community Innovation Survey[2], an inquiry about the innovative activities in the Flemish economy, carried out bi-annually since 1993. The CIS methodological standards comprise a stratified random sampling

[2] This survey is conducted by the Centre for Research & Development Monitoring (ECOOM) on behalf of the Flemish government.

procedure to ensure representativeness of the sample for the whole economy. The data consists of one cross-section of the Flemish economy surveyed in 2013 about their activities in the period spanning 2010-2012. The sample covers firms in the manufacturing as well as in the services sector. 3871 firms responded to the survey of which 15 were dropped because of extreme sales productivity and 85 because of extreme productivity growth. Of the remaining firms 40.6 %. reported to have had at least one product innovation in the surveyed period. I restrict the sample to product innovators only as the interest lies in relating the effectiveness of using lead time advantages for appropriation of innovation to the openness of the innovation process in general and the use of external information sources to innovate more specific. The definition of an innovating firm follows the international guidelines for collecting innovation data from the business sector as described by the OSLO manual (OECD Publishing, 2005). Considering item non-response on the variables used in our specifications, the final estimation samples count about 850 observations.

III.A. Dependent Variable

The outcome variable in our analyses measures how effective the use of lead time advantages in new product and process development was in sustaining or improving the competitive position of the firm. LEAD TIME is defined on a 4-point Likert scale and indicates whether lead time advantages were contributing to a large, mediocre, or small degree to competitive advantage build up from innovation. Companies could also indicate they did not make use of lead time advantages.

III.B. Regressors of Interest

The survey inquired firms about how intensely the following information sources were used in their innovation (knowledge sourcing) strategy:

a. Suppliers

b. Clients from the private sector

c. Clients from the public sector

d. Competitors

e. Consultants

f. Universities

g. Government institutions, research labs

h. Conferences, trade fairs, exhibitions

i. Scientific literature and professional publications

j. Professional and sectorial associations

On a 4-point Likert scale companies could indicate whether the source had large (value 3), medium (value 2), or low (value 1) importance in their knowledge sourcing strategy or that the source was not used (value 0). Knowledge sourcing BREATH and DEPTH are respectively defined as the total number of external information sources used from the list and the number of sources with a large importance (cfr. Laurson and Salter, 2006). Companies have an average knowledge sourcing BREADTH of about 7 and an average knowledge sourcing DEPTH of about 2.

The list was also further aggregated into logical categories by taking the maximum value from the relevant items from the list: (a) SUPPLIERS with an average importance of 2.1 , (b-

c) CLIENTS with an average importance of 1.8, (d) COMPETITORS with an average importance of 1.5, (e) CONSULTANTS with an average importance of 1.1, and (f-j) SCIENCE – ACADEME with an average importance of 1.5.

The variable CLOSED is an indicator variable that is set to 1 when the company developed its innovation without third party involvement, meaning the firm developed the innovations launched in the survey period by themselves without cooperation from other firms or institutions and without subcontracting innovative activities. 33 % of firms were CLOSED.

III.C. Control Regressors

Patent stock for firm i in year t, was retrieved by applying the following formula.

$$PS_{it} = (1 - \delta)\, PS_{it-1} + patent\ applications_{it}$$

Where δ, the constant knowledge depreciation rate, is set to 15%. PATENT INTENSITY further scales the patent stock per employee. The patent applications are aggregated on the family level to obtain unique inventions. To mitigate endogeneity concerns this variable enters our specification as measured in 2010, i.e. with a lag of 2 years. The PATENT INTENSITY varies between 0 and 1 and on average a firm has 1 patent per 50 employees. 77 % of the firms did not apply for patents in the past. The fact that the upper limit of the value range for this variable is 1 is purely due to the coincidence that the most intensely patenting company seems to have exactly 1 patent per employee.

I measure R&D INTENSITY as intramural R&D spending per employee in 2012.

Further general controls on firm size and age, EMPLOYMENT and AGE, are available. Large and established firms might more easily profit from lead time advantages and more easily build external information networks or be in a better position to open up the innovation process. Therefore, these potential effects should be controlled for in the analysis. Firms are between 3 and 179 years old and have between 2 and 4280 employees. 30 % of the firms in the estimation sample realized their product innovations without spending on intramural R&D, whereas the most R&D intensive firm spent 231500 euro on internal R&D per employee. Finally, sector dummies are available to be able to control for inter-sectorial differences.

Table I with the summary statistics shows a healthy amount of variation amongst the observations in the estimation sample. Because of the skewed distribution of age and size, their values will be log transformed for the regression analysis. The sectorial distribution of the sample, depicted in table II, shows quite some variation, but there is a substantial amount of observations in each sector. From the pairwise correlation table III we can read that none of the correlations between the independent variables of interest is excessively high.

Table I. Descriptive Statistics

VARIABLE	DESCRIPTION	N	μ	σ	MIN	MAX
LEADTIME	4-point Likert indication of how efficient lead time was with regard to appropriation.	872	1.15	1.18	0	3
BREADTH	Total number of external information sources used.	872	7.42	3.11	0	11
DEPTH	Total number of external information sources for which the company indicated the maximum importance.	872	2.05	1.68	0	11
SUPPLIERS	Indicates on a 4-point scale how intensively the company used suppliers as a source of information.	863	2.12	0.90	0	3
CLIENTS	Indicates on a 4-point scale how intensively the company used clients as a source of information.	860	1.83	1.09	0	3
COMPETITORS	Indicates on a 4-point scale how intensively the company used competitors as a source of information.	863	1.53	0.95	0	3
CONSULTANTS	Indicates on a 4-point scale how intensively the company used consultants as a source of information.	859	1.11	1.00	0	3
SCIENCE	Indicates on a 4-point scale how intensively the company used science/academia as a source of information.	860	1.48	1.00	0	3

Table I. Descriptive Statistics Cnt'd[3]

VARIABLE	DESCRIPTION	N	μ	σ	MIN	MAX
CLOSED	Indicates whether the company realized its innovation without third-party involvement.	872	0.33	0.47	0	1
PATENT INTENSITY	Depreciated patent stock per employee	872	0.02	0.07	0	1
R&D INTENSITY	R&D expenditures (2012) per employee	872	11.88	26.78	0	231.5
AGE	Age of the firm	872	26.49	18.68	3	179
EMP	Number of employees	872	138.86	374.65	2	4280

[3] From the sample, 20 companies were dropped due to a suspiciously high sales product (>15mio per employee) or productivity growth (x2), indicating there might be some error in the response (i.e. the unit which was reported for might not be identified since there is a 'mismatch' between 2 measures of size, employment and turnover).

Table II. Sector Distribution for N=872

Sectors	SECTOR DESCRIPTION	N	R. Freq
Sector 1	Food, beverage, tobacco	120	0.14
Sector 2	Textile, clothing and leather industry	38	0.04
Sector 3	Manufacture of cokes, chemicals, pharmaceuticals, rubber and plastic	91	0.1
Sector 4	Manufacture of non-ferro minerals, metals and metal products (no machinery and equipment)	83	0.1
Sector 5	Manufacture of electrical equipment, IT-products, electronic and optical products	54	0.06
Sector 6	Manufacture of machinery, equipment, tools and transport	74	0.08
Sector 7	Wholesale	77	0.09
Sector 8	Telecomunication, software design and programming, computer-consultancy, information services, architects and engineering, R&D	223	0.26
Sector 9	Remaining sub-sectors	112	0.13

Table III. Bivariate correlations

Pairwise correlation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. LEADTIME	1											
2. BREADTH	0.28	1										
3. DEPTH	0.22	0.45	1									
4. SUPPLIERS	0.17	0.48	0.48	1								
5. CLIENTS	0.24	0.57	0.48	0.23	1							
6. COMPETITORS	0.17	0.64	0.54	0.38	0.46	1						
7. CONSULTANTS	0.19	0.62	0.46	0.24	0.28	0.35	1					
8. SCIENCE	0.23	0.68	0.52	0.35	0.29	0.47	0.45	1				
9. CLOSED	-0.17	-0.15	-0.12	-0.18	-0.04	-0.12	-0.18	-0.09	1			
10. PAT. INTENSITY	0.07	0.11	0.06	-0.02	0.09	-0.01	0.16	0.12	0	1		
11. R&D INTENSITY	0.18	0.22	0.21	-0.02	0.19	0.13	0.26	0.22	-0.03	0.34	1	
12. LNAGE	0.03	0.03	0.05	0.08	0.04	0.04	0.02	0.00	-0.08	-0.1	-0.13	1
13. LNEMP	0.12	0.19	0.11	0.06	0.08	0.12	0.14	0.16	-0.12	0.00	0.05	0.25

IV. RESULTS

In the regression analysis, I study an ordered outcome variable indicating the effectiveness of lead time advantages in the appropriation strategy of firms and relate it to measures of openness of the development process and characteristics of the external knowledge sourcing strategy.

IV.A. Knowledge sourcing breadth and depth (H1, H2)

Table IV contains the results from ordered response models assessing the relation between the effectiveness of use of lead time advantage (LEAD TIME EFFICIENY) in innovation and knowledge sourcing BREATH and DEPTH. The initial specification only includes the variables of interest. To allow for an increase or decrease I include also the squares of the variables. In line with H1 and H2 I find that knowledge sourcing BREATH and DEPTH have diminishing marginal returns on the effectiveness of using lead time advantage in the competitive strategy, all coefficients being significant at least at the 5% level. Stacking PATENT and R&D INTENSITY into the specification, I find that innovation input is positively related to the outcome variable. The coefficients on the variables of interest do not change much and remain significant at the same significance levels. Further adding general firm level controls also does not change the effects on the variables of interest. I find that bigger firms (LNEMP) are more effectively using lead time advantages. The coefficient on LNAGE is insignificant. A test on the joint significance of the sector dummies indicates that the effectiveness of lead time advantages is sector specific, the F-test being significant at the 5% level.

Table IV. Ordered Probit Regressions of Efficiency of Using Lead Time Advantages for Appropriation on Breadth and Depth of Knowledge Sourcing

b/(se)	LEAD TIME	LEAD TIME	LEAD TIME
BREADTH	0.207***	0.189***	0.194***
	(0.063)	(0.063)	(0.063)
BREADTH_SQUARED	-0.009**	-0.009*	-0.010**
	(0.005)	(0.005)	(0.005)
DEPTH	0.303***	0.285***	0.288***
	(0.064)	(0.065)	(0.065)
DEPTH_SQUARED	-0.031***	-0.031***	-0.031***
	(0.009)	(0.009)	(0.009)
CLOSED		-0.321***	-0.309***
		(0.085)	(0.087)
PATENT INTENSITY		0.012	0.1
		(0.624)	(0.642)
R&D INTENSITY		0.005***	0.005***
		(0.002)	(0.002)
LNAGE			-0.057
			(0.064)
LNEMP			0.065**
			(0.032)
Sectors			Incl.**
cut1	1.241***	1.052***	1.156***
_cons	(0.198)	(0.204)	(0.294)
cut2	1.620***	1.438***	1.551***
_cons	(0.200)	(0.205)	(0.296)
cut3	2.333***	2.163***	2.287***
_cons	(0.203)	(0.208)	(0.298)
Pseudo R2	0.049	0.061	0.073
#obs	872	872	872
Wald	110.542	136.886	162.295
Sig	0.000	0.000	0.000

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.)*

IV.B. Types of external information and openness of the innovation process (H3 and H4)

Table V contains the results from ordered response models assessing the relation between the effectiveness of the use of lead time advantages and the types of external information channels. The initial specification only includes the variables of interest. In line with H3 and H4 I find that vertically related information sources (CLIENTS, SUPPLIERS and SCIENCE) are positively impacting LEAD TIME, the coefficients being significant at least at the 5% level. The coefficients on horizontally related sources (COMPETITORS and CONSULTANTS) are insignificant. When adding CLOSED to the specification, I find a negative and significant (1% level) relation between LEADTIME and having a CLOSED innovation process, in support of H4. Stacking PATENT and R&D INTENSITY into the specification, I find that innovation input is positively related to the outcome variable. The coefficients on the variables of interest do not change much and remain significant at the same significance levels. Further adding general firm level controls also does not change the effects on the variables of interest. I find that bigger firms (LNEMP) are more effectively using lead time advantages. The coefficient on LNAGE is insignificant. A test on the joint significance of the sector dummies indicates that the effectiveness of lead time advantages is sector specific, the F-test being significant at the 5% level.

Table V. Ordered Probit Regressions of Efficiency of Using Lead Time Advantages for Appropriation on Intensity of Use of Specific of Knowledge Sources

b/(se)	LEADTIME	LEADTIME	LEADTIME	LEADTIME
SUPPLIERS	0.127**	0.101**	0.125**	0.130**
	(0.050)	(0.050)	(0.051)	(0.052)
CLIENTS	0.206***	0.216***	0.200***	0.191***
	(0.042)	(0.042)	(0.042)	(0.042)
COMPETITORS	-0.028	-0.039	-0.034	-0.042
	(0.052)	(0.052)	(0.053)	(0.053)
CONSULTANTS	0.079*	0.053	0.023	0.018
	(0.045)	(0.045)	(0.046)	(0.047)
SCIENCE	0.160***	0.167***	0.148***	0.113**
	(0.048)	(0.048)	(0.048)	(0.049)
CLOSED		-0.357***	-0.359***	-0.340***
		(0.086)	(0.087)	(0.089)
PATENT INTENSITY			-0.01	0.113
			(0.630)	(0.647)
R&D INTENSITY			0.005***	0.005***
			(0.002)	(0.002)
LNAGE				-0.059
				(0.064)
LNEMP				0.070**
				(0.032)
Sectors				Incl. **
cut1	0.784***	0.593***	0.622***	0.613**
_cons	(0.123)	(0.132)	(0.133)	(0.257)
cut2	1.167***	0.981***	1.013***	1.014***
_cons	(0.126)	(0.133)	(0.134)	(0.258)
cut3	1.880***	1.701***	1.739***	1.751***
_cons	(0.131)	(0.138)	(0.139)	(0.260)
Pseudo_R2	0.042	0.05	0.056	0.068
#obs	852	852	852	852
Wald	92.419	109.567	121.986	148.858
Sig	0.000	0.000	0.000	0.000

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.)*

IV.C. Diminishing Marginal Returns to Breadth and Depth – Further Analysis

To further gauge the diminishing marginal returns to knowledge sourcing breadth and depth, I plot the linear predictions of LEADTIME EFFICIENY relative to the values taken by breadth (figure I) and depth (figure II). Since the cut-off points in the estimation are ordered along this linear prediction, higher values of the linear prediction correspond to higher values of estimated LEADTIME EFFICIENY.

Figure I. Linear Prediction for LEADTIME in Relation to Knowledge Sourcing BREADTH Derived From the Ordered Probit Estimation.

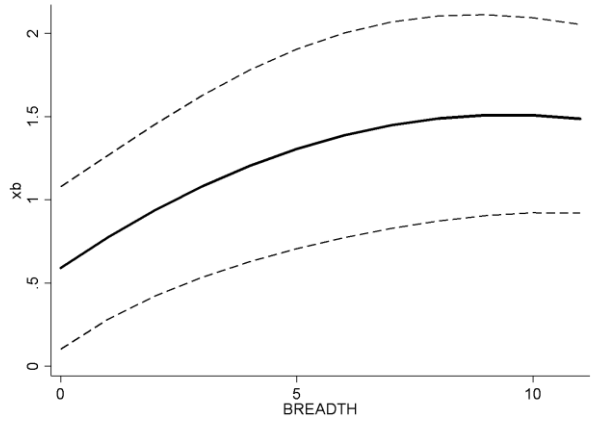
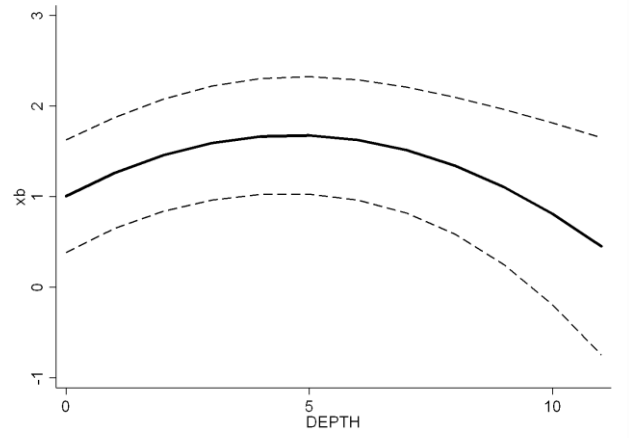


Figure II. Linear Prediction for LEADTIME in Relation to Knowledge Sourcing DEPTH Derived From the Ordered Probit Estimation.



From figure I we can read that the positive returns to knowledge sourcing breath are diminishing in nature. There is no clear point of inflection where the returns become negative.

Figure II indicates that the (initially positive) returns to knowledge sourcing depth are diminishing in nature. However, at around the value of 5 the predicted latent probability start to decrease, indicating that at higher values of depth the returns become negative. Next, I estimate separate coefficients for breadth, depth and their squares by interacting with a dummy variable that splits the sample at the mean of R&D Intensity. I argue here that if firms made an investment in absorptive capacity that could mean that they will have a larger effective attention pool to be allocated over the different channels or that firms will be able to make less 'misallocation' of attention. By plotting the linear predictions (see Figures III and IV) one can see that firms having an R&D intensity above the mean are not confronted with substantially diminishing marginal returns neither for breadth nor depth (in the regressions the coefficient on the squared terms are insignificant), firms with R&D intensities below the mean do exhibit substantially diminishing marginal returns.

Figure III. Linear Predictions for LEADTIME in Relation to Knowledge Sourcing BREADTH
– Separate Slopes for High vs. Low R&D Intensive Firms

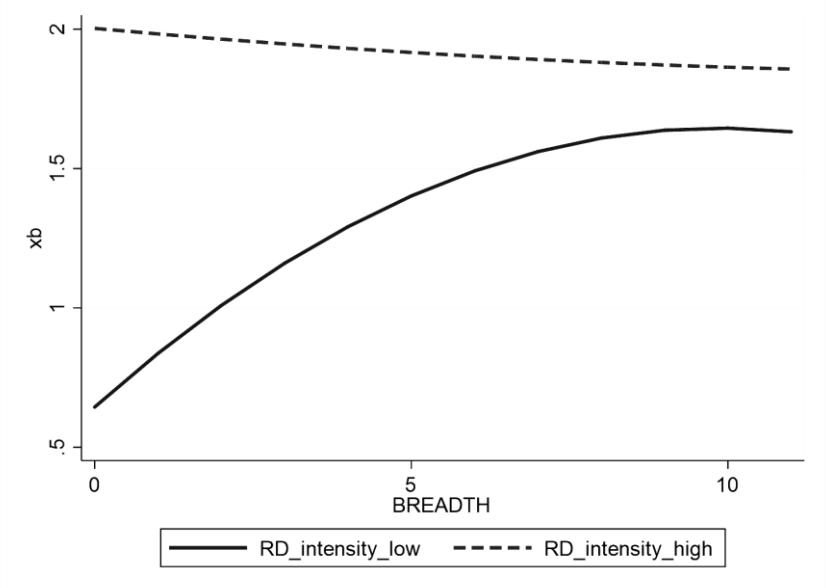
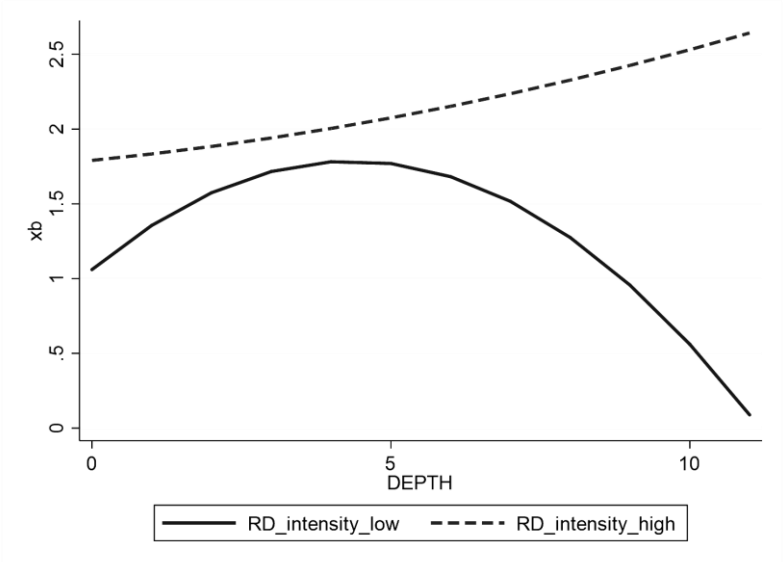


Figure IV. Linear Predictions for LEADTIME in Relation to Knowledge Sourcing DEPTH – Separate Slopes for High vs. Low R&D Intensive Firms



IV.D. Sample split new-to-market vs. new-to-firm

To gauge to which extent my results are driven by first-to-market innovators or imitators I conduct a sample split analysis. Indeed, to successfully imitate an existing innovation it might be of prime importance to have a broad overview of existing problems and solutions in the field. On the other hand, successfully launching a new-to-market innovation will probably require more profound knowledge. Based on the survey response I split the sample into firms having introduced an entire new product as first to the market and firms not having done so. See table VI for descriptive statistics by subsample. In table VII I now only estimate the full specification and find that both knowledge sourcing breadth and depth matter with regard to having had effective benefit from lead time advantage for first-to-market product innovators. For firms that only had new-to-firm innovations (imitations), only knowledge sourcing breadth seems to matter. In the regressions with the specific external information channels included as regressors, the coefficients are only significant when estimating for first-to-market innovators.

Table VI. Descriptive Statistics for Split Sample

VARIABLE	DESCRIPTION	NOVELTIES	NO NOVELTIES	T-TEST
LEADTIME	4-point Likert indication of how efficient lead time was with regard to appropriation.	1.31	0.85	***
BREADTH	Total number of external information sources used.	7.97	6.38	***
DEPTH	Total number of external information sources for which the company indicated the maximum importance.	2.23	1.72	***
SUPPLIERS	Indicates on a 4 point scale how intensively the company used suppliers as a source of information.	2.12	2.1	
CLIENTS	Indicates on a 4 point scale how intensively the company used clients as a source of information.	2.05	1.40	***
COMPETITORS	Indicates on a 4 point scale how intensively the company used competitors as a source of information.	1.60	1.38	***
CONSULTANTS	Indicates on a 4 point scale how intensively the company used consultants as a source of information.	1.23	0.89	***
SCIENCE	Indicates on a 4 point scale how intensively the company used science/academia as a source of information.	1.31	0.85	***

CLOSED	Indicates whether the company realized its innovation without third party involvement.	0.31	0.37	
PATENT INTENSITY	Depreciated patent stock per employee	0.018	0.0078	**
AGE	Natural logarithm of age of the firm	15	5.08	**
EMP	Natural logarithm of number of employees	26.37	26.7	

Table VII. Ordered Probit Regressions of Efficiency of Using Lead Time Advantages for Appropriation on External Knowledge Sourcing Variables – Sample Split on Having a Market Novelty

	FIRMS HAVING MARKET NOVELTIES		FIRMS HAVING NO MARKET NOVELTIES	
b/(se)	**LEAD TIME**	**LEAD TIME**	**LEAD TIME**	**LEAD TIME**
BREADTH	0.179** (0.087)		0.299*** (0.103)	
BREADTH_SQUARED	-0.008 (0.006)		-0.022*** (0.008)	
DEPTH	0.339*** (0.080)		0.142 (0.121)	
DEPTH_SQUARED	-0.035*** (0.010)		-0.015 (0.019)	
CLOSED	-0.323*** (0.107)	-0.343*** (0.110)	-0.275* (0.156)	-0.312** (0.159)
SUPPLIERS		0.164** (0.065)		0.119 (0.087)
CLIENTS		0.172*** (0.054)		0.133* (0.074)
COMPETITORS		-0.048 (0.065)		0.010 (0.097)
CONSULTANTS		0.008 (0.058)		0.000 (0.085)
SCIENCE		0.153** (0.060)		0.006 (0.092)
general Firm Level controls & Sector dummies	Included	Included	Included	Included
Pseudo R2	0.074	0.068	0.06	0.049
#obs	576	568	296	284
Wald	113.712	103.893	39.564	31.274
Sig	0	0	0.001	0.027

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.)*

V. DISCUSSION AND CONCLUSION

This paper, based on an analysis of Community Innovation Survey data, aimed to find out if certain innovation strategies might be conducive for achieving an effective lead time advantage with respect to innovation. In particular, external knowledge sourcing were studied as catalysts of innovation appropriation by means of obtaining a lead time advantage over rivals' products.

I find firms drawing information from vertically related information sources, consumers, suppliers, and science are benefiting from more effective appropriation from lead time advantages. The effects of drawing information from horizontally related sources, competitors and consultants, are insignificant. Returns to knowledge sourcing breadth, I find, are diminishing in nature. Further, I find an inverted-U relation between the efficiency of using lead time advantage for appropriation on the one hand and depth of the external knowledge sourcing strategy on the other. Lead time advantages can thus seemingly be created through diverse and deep knowledge sourcing, although there are diminishing returns. Furthermore, I find that firms with a closed innovation process, i.e. indicating they realized their innovations or imitations without active involvement of external parties, are having a harder time to profit from lead time advantages. The results are mainly driven by first-to-market innovators, however, new-to-firm innovators are seemingly still benefiting from a broader external knowledge sourcing strategy, possibly reflecting that effective imitation requires firms to have a bird's eye view of the innovative landscape to out-imitate their competition. Apart from the information sourcing strategy also cooperation during the development process seems to matter, as firms with a closed development process are having it harder to profit from lead time advantages.

These results can be interpreted in the light of recent literature on open innovation (e.g.

Chesbrough, 2017) which states that managing the impact of open innovation on internal innovation is one of the main future challenges of open innovation. They are also in line with literature addressing the impact of the external knowledge sourcing profile on innovation performance (e.g. Laursen and Salter, 2006; Frenz and Ietto-Gillies, 2008; Leiponen and Helfat, 2010). If one considers that timeliness is an important dimension of successful innovation, one could argue that my results reflect that broad and deep information sourcing, especially from vertically related sources, is contributing to successful innovation. The inverted U-relation I find is in line with Chesbrough's (2017) argument that innovation could be slowed down if companies do not invest properly into the capacity to handle the influx of external information. Additional evidence for this argument was found by splitting the sample at the mean value of R&D intensity. Firms having a higher absorptive capacity, as proxied by a high R&D intensity, do not exhibit a significant decrease in their marginal returns to both breadth and depth. This result is in line with the complementarity between internal R&D and external knowledge acquisition as found by Cassiman and Veugelers (2006).

The digital revolution, being a main contributor by the increasing information storage, processing, and retrieval capacity (Hilbert & López, 2011), enabled firms to become ever more agile (Overby et al., 2006) and thereby, most likely, contributed to the rise of superstar firms in concentrated industries (cf. e.g. Mcafee & Brynjolfsson, 2008). One interesting avenue for future research would be to find out how the relation between external knowledge sourcing strategy and lead time advantage is moderated by investments in ICT capacity. My results should be interpreted with adequate caution and be considered as correlational evidence as a causal relation could not be identified. Good instruments for the information sourcing variables would be hard to come by given that the knowledge sourcing strategy decisions are potentially highly interrelated with other company characteristics. Natural experiments that influence the

companies' knowledge sourcing profile are, to my knowledge, non-existent. However, the analysis does include adequate controls for innovation input (R&D expenditures) and output (patent intensity).

Chapter II

Information Leakage, Imitation, and the Patent System: Mansfield Revisited.[4]

Abstract
From a firm perspective two competing forces are driving the decision to invest in innovation. On one hand, innovative performance is an important driver of firm growth. On the other hand, investments in innovation suffer from negative externalities or spillovers to other firms. Moreover, not only can a firm see a part of its knowledge base leaked to competitors, also imitation might be induced. To preempt imitation firms might protect their inventions by means of patents. However, by taking out a patent a firm also conveys information about the functioning of the invention to competitors. Using the seminal framework on knowledge leakage by Mansfield (Mansfield, 1961, 1985; Mansfield et al. 1981) we contribute to the discussion on the functioning of the contemporary patent system. Theoretically, patents should provide protection from imitation. In return for a temporary monopoly on the protected invention, the patentee trades off secrecy by disclosing the functionality of the invention to the public in the patent document. Empirically, in a recursive system of equations using Flemish survey data on the R&D activities of companies in 2012-2013, we relate imitation and knowledge dissemination propensities to firm level patenting intensities. We find that SMEs that are heavily engaged in patenting are being less confronted with imitation. The effect of patents on the dissemination of R&D (findings) is, however, insignificant. Therefore, we conclude that patent disclosures do not significantly harm the appropriability conditions for inventions, but help to protect, at least partly, against imitation, as it has been originally envisaged by policy.

[4] This chapter is co-authored with Dirk Czarnitzki and currently under further preparation for journal submission.

I. INTRODUCTION

From a firm perspective two competing forces are driving the decision to invest in innovation. On one hand, innovative performance is an important driver of firm performance and this can encourage firms to invest. In 1912, Joseph Schumpeter defined economic innovation in "The theory of economic development". His definition encompasses: introduction of new goods on the market; introduction of new production methods; opening of new markets; conquest of new sources of supply; carrying out of the better organization of an industry. In his book *Capitalism, Socialism and Democracy* Schumpeter acknowledged competition based on innovation as the most effective way to acquire a competitive advantage (Schumpeter, 1944). On the other hand, investments in innovation suffer from negative externalities or spillovers to other firms (e.g. Arrow, 1962). Not only can a firm see a part of its knowledge base leaked to competitors, also imitation might be induced. This in turn reduces the a priori incentives to invest. Governments have put patent systems in place to effectively counter this harmful effect of imitation by granting innovators a temporary monopoly to their innovations. At the same time a well-functioning patent system promotes the dissemination of useful knowledge by requiring the patentee to disclose the invention*" in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art"* (EPC, 2013: art. 83).[5] It may thus not only lead to imitation but possibly also to an acceleration of technological progress by providing detailed information about inventions. Such information might not only be used for imitation (which in its narrow sense is ruled out because of the patent protection),

[5] The dual function of patents, facilitating appropriability of innovations and disclosing the characteristics of the invention, can also enable innovators to better negotiate licensing deals with, for example, follow on innovators (e.g. Gans et al., 2008; Arora et. al., 2001; de Rassenfosse, 2016).

but for superior follow-on inventions that make the patented first generation invention possibly obsolete before the legally granted patent monopoly rights expire.

However, to date, empirical work on imitation is largely descriptive in nature (Mansfield, 1981, 1985; Mansfield et al. 1961 Levin et al., 1987). Mansfield, Schwartz, & Wagner (1981) ascertain that in their sample of 48 product innovations from major Northeastern US firms in the chemical, drug, electronics, and machinery industries about 60 percent of the innovations that were patented were imitated within 4 years. However, they also state that approximately half of the firms they studied would not have introduced their invention when it could not be patented. Earlier on Mansfield (1961) showed that imitation tends to follow faster when the profitability of the invention is high. Mansfield (1985) showed that for a random sample of 100 highly R&D active US firms in the thirteen major manufacturing industries in more than half the cases information regarding major R&D decisions leaks to the competition in less than 18 months. The information regarding the operation of a novelty leaks out in about a year after the product has been developed. Given this fast information leakage it is of no surprise that subsequent, swift imitation might occur frequently. An ill-defined patent system may thus even result in negative welfare effect (Boldrine & Levine, 2013). In this paper, we aim to follow up on the seminal contributions of Mansfield et al. by relating the occurrence of knowledge dissemination and the event of imitation to firms' patenting intensity while controlling for other relevant firm level characteristics. The patent system's overall effect on innovation depends on both the property rights it allocates to prevent imitation (the 'appropriation function') and the useful knowledge it helps to disseminate (the 'dissemination function') (see e.g. Fromer, 2009). The present paper empirically addresses the question of whether patents are functioning as envisaged.

We use Belgian survey data on the R&D activities of SMEs for 2012-2013. Amongst other things, the survey inquired the companies about whether R&D decisions leaked to competitors and whether the innovations resulting from their R&D were subsequently imitated. This novel information allowed us to address our research question: *Are patents effective means to preempt imitation while facilitating the dissemination of useful knowledge?*

Taking out patents does seem to have the desired effect of decreasing the probabilty of being imitated. This may be interpreted as a signal that the functioning of the patent system is well behaved in terms of the enforceability of IPR. We find the effect of taking out patents on information leakage to be insignificant. However, a lot of the imitation can be explained by information leakage earlier on in a staged process.

The remainder of this paper is structured as follows: in section II hypotheses are developed based on extant literature. Next, in section III, the method used in conducting this research is discussed. A description of the data and variables used is given and the estimation method is briefly explained. Section IV and V summarize the results from the regression analyses which are subsequently discussed in section VI.

II. RELATED LITERATURE AND HYPOTHESES DEVELOPMENT

Even though the patent system has undergone major changes over time, its effectiveness is often questioned (see e.g. Boldrin & Levine, 2013). Stiglitz (2008), for example, argues that IPRs are not the most efficient way to induce innovation in firms and sometimes can even hinder technological progress. He explains that while researchers and academics work hard to get their ideas disseminated, by contrast Intellectual Property (IP) Rights are designed to restrict the use of knowledge in one way or another. Therefore, a poorly designed IP regime that creates excessively strong intellectual property rights may eventually impede innovation. The fact that

many of the most important intellectual advances are not covered by patents (e.g. the Turing machine and ideas like asymmetric information) is indicative of other, more efficient ways to finance and produce research. When the research goal is clearly defined a prize system may be an alternative way to create incentives, using competitive markets to widely disseminate the innovation. Otherwise, government funded research and grants are good instruments to produce innovation. The main drawback being that government is picking who undertakes the research, which is not necessarily who has the best prospects of succeeding. Patent notice, the notification of the public of the existence of the patent by adding the words "patented" or "U.S. Patent No", seems often to be failing (Bessen & Meurer, 2008) because boundaries to IP are often fuzzy. Inventers might deliberately choose to obfuscate the notice information because of incomplete appropriation of the benefits that stem from disclosure (Menell & Meurer, 2013). In a worst-case scenario, this could lead to technology gridlock (Heller, 2008) – a situation in which follow on innovation does not occur because follow on inventions needs to draw on fragmented and uncertain IP. Licensing deals might be hindered by uncertainty surrounding the scope and extent of IP rights (Gans et al. 2008). Moreover, when the upstream technology base is fragmented, the "royalty stack" might make it unprofitable for the downstream firm to conduct the R&D (Lemley & Shapiro, 2007).

Public policy analysis of optimal patent regimes is often framed as a trade-off between static and dynamic efficiency (Ordover, 1991). Patents, from this perspective, perform two main functions in trying to maximize these efficiencies. They, on one hand, protect firms' innovations from imitation, granting them a temporary monopoly to increase the incentives to invest in innovation (the 'appropriation' function) and, on the other hand, disseminate useful knowledge to facilitate follow-on invention (the 'dissemination' function).

In this paper we address the question of whether these two functions work as they were originally envisaged to work by policy. Theoretical modelling work on patents and imitation includes Horstmann et al. (1985); Anton & Yao (2004); Bhattacharya & Guriev (2006). Horstmann et al. (1985) predict that neither all inventions are patented nor all patented inventions are free from imitation. Anton & Yao (2004) find, amongst other things, that the occurrence of imitation is contingent on the size of the inventive step. Bhattacharya & Guriev (2006) conclude from their model that an open or patented sale provides legal support for exclusion but also involves leakage of a certain portion of the knowledge in the process of filing a patent. The empirical question of whether patents impact the frequency and speed of dissemination and imitation as envisaged is an interesting question that, however, remains under-researched. To frame our hypotheses, we need to draw upon several branches of literature. First, regarding the 'appropriation function', we look at patents as an obstacle to imitation (see H1 below). Second, regarding the 'dissemination function', patent law provides us a clear indication of how patents can serve as enablers of knowledge disclosure (see H2 below). Third, we connect both functions by considering knowledge disclosure as a driver of imitation (see H3 below).

The 'appropriation' function of patents

Governments around the world invoked a patent system to alleviate a concern here expressed by Mansfield et al. (1981: 907): *"If firms can imitate an innovation at a cost substantially below the cost to the innovator of developing the innovation, there may be little incentives for the innovator to carry out the innovation."* Mansfield et al. (1981) acknowledge the functioning of this system as they find that half of the firms they studied would not have

introduced their invention if it could not be patented. However, it often happens that potential imitators engage in R&D themselves to find a way to invent-around a patent, for example by making a similar product offering through another technique.

For patents to be valuable to innovators and enable them to recoup their R&D investments they should grant them a temporary right to exclude others from the production or use of the invention. In other words, patents should inhibit imitation of the patented invention by competitors. Izhak et al. (2016) find for the pharmaceutical industry that the probability of imitation increases with patent length and decreases with patent breath, suggesting that society would benefit from having broad and relatively short lived patents. Heger & Zaby (2018) also find that having broader patents effectively deters market entry by invent-around imitators. Companies that are intensively patenting their inventions by for example taking out multiple patents on closely related inventions are mimicking this type of broader patent protection, therefore we hypothesize :

H1: Firms that intensely protect their knowledge through the patent system, as measured by the company patent application stock, are less confronted with imitation.

The 'dissemination' function of patents

Patent citations are commonly used as proxies for knowledge spillovers, assuming patents serve as disclosure mechanisms (as in Jaffe, Trajtenberg & Henderson 1993). However, few studies have gauged the impact of patents on dissemination more directly. By construction, firms that apply for a patent make information about the nature of their R&D investments public. The 15th edition of the European Patent Convention (EPC, 2013) states that *"The European patent application shall disclose the invention in a manner sufficiently clear and*

complete for it to be carried out by a person skilled in the art." (art 83). From the viewpoint of cumulative innovation, patents constitute an important mechanism by which firms can learn from their precursor innovators. Many patents are granted quite early in the innovation process, with a lot of follow on work needing to be done before the crude invention is ready for actual use (Mazzoleni & Nelson, 1998:277-278). Patents could thus potentially enhance the dissemination of technological knowledge, including information regarding R&D investments.

H2: Firms with a larger patent application stock are significantly more likely to leak important R&D investment decisions to rivals.

However, since long, economists suggest the patent dissemination function might be flawed. Bessen (2005) developed a model to assess whether the disclosure requirement of the patent system encourages the diffusion of inventions. He studied a situation in which firms choose between patents and trade secrecy to protect inventions and concluded that "diffusion of the technical information embodied in inventions is not enhanced by the patent system and may well be delayed" (Bessen, 2005: p. 127). He attributed this result mainly to the fact that firms use patents to reduce or eliminate imitation. This result also holds in a scenario where licensing is available. In a scenario with licensing, he argued, licenses are given when there is a credible threat of imitation. Therefore, because patent rights limit the opportunities for imitation, the extent to which licenses are used in a no-patent regime could well be higher than when patents were available. Machlup & Pensrose (1950, p27) state "only unconcealable inventions are patented; concealable inventions remain concealed." The claimed disclosure function of patents is as such based on an "apples to oranges comparison". Moreover, survey evidence suggest not much value is placed on the information disclosed in patents (Macdonald, 1998; Tang et al.,

2001; Cohen et al., 2002). Patents are instead used for reasons such as keeping track of competitors or checking for infringement (Oppenheim, 1998). Since inventors might deliberately be hiding, obfuscating, and distorting notice information (Menell & Meurer, 2013), mapping the technology neighborhood might be hard and disclosure could be impeded. Furthermore, Lamoreaux & Sokoloff (1999) find empirical support for a shift towards internalizing the R&D process within the firm, effectively limiting the role of patents as signals for prospective buyers to make an informed decision.

In line with the above, we might expect no significant effect of patent application stock on diffusion of technological information (regarding R&D investment decisions).

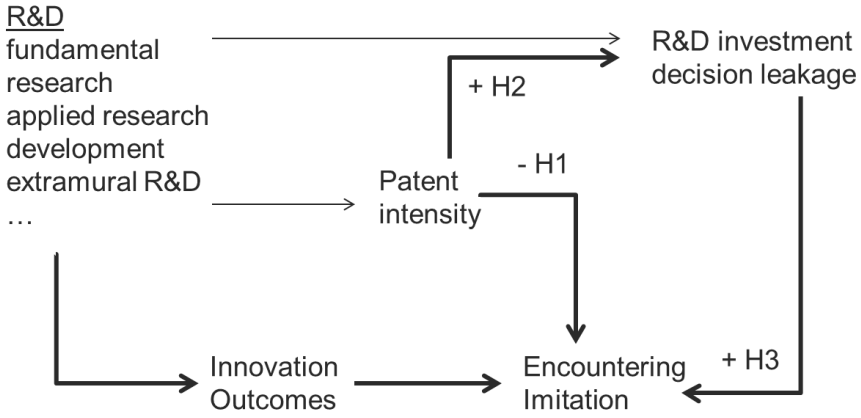
Knowledge disclosure as a driver of imitation

Given that information about investment decisions leaks out fast and competitors can often invent around patents, it is easy to see that imitation might occur rapidly (Mansfield, 1985). Imitation can thus occur as a staged process. If knowledge about the field in which an innovator is invested or even the nature of these investments leaks to competitors, they might start sooner with their imitative R&D effort. Also, the potential imitators might anticipate by building up relevant absorptive capacity. Increased R&D investment builds the absorptive capacity of a company to profit from incoming spillovers (Cohen & Levinthal, 1989). This in turn might lead to higher success rates of eventual imitation. Anton & Yao (2004) in their theoretical model assume explicitly that knowledge revealed through patent disclosures eases the imitation effort. In line with the above, we hypothesize:

H3: Leakage of a company's R&D investment decisions positively impacts the probabilty that their products and processes get imitated.

An overview of the hypotheses framework can be found in figure I.

Figure I. Hypotheses framework



III. METHODOLOGY

III.A. Data – Flemish R&D Survey & PATSTAT

The data set used to conduct the analysis originates from the Flemish R&D Survey , an inquiry about the R&D activity in the Flemish economy carried out bi-annually. The R&D methodological standards comprise a stratified random sampling procedure and a comprehensive non-response analysis to ensure representativeness of the sample for the Flemish economy as a whole. The data consists of one cross-section of the Flemish economy surveyed in 2014 about their activities in the period spanning 2012-2013. We use the survey carried out in 2014 since it includes unique questions on R&D investment diffusion and imitation of products and processes. Companies were asked whether they were confronted with

leakage of important R&D investment decisions and imitation. Additionally, they were inquired about the time it took for these events to occur. The sample covers firms in the manufacturing as well as the services sector. We restrict the sample to R&D performing firms as the interest lies in imitation of product and process innovations which required upfront investments. Considering item non-response on the variables used in our specifications, the final estimation sample counts 423 observations. Of those, little under 100 companies reported estimations of investment decision leakage speed and imitation speed. Our data for Belgian SMEs shows comparable leakage speed of R&D investment decisions to the average of 12 to 18 months that Mansfield (1985) found for manufacturing industries:

Table I. Speed of Investment Decision Leakage

Sector/Months	**A. Less than 6**	**B. 6 to 12**	**C. 12 to 18**	**D. 18 and more**	**Total**	**Mean**
Primary	1	8	5	4	18	13.78
Secondary	NA	9	6	15	30	18.4
Tert. & Quat.	7	9	12	6	34	12.5
Total	8	26	23	25	82	14.93

Further, Mansfield (1985) found that the detailed nature and operation of an innovation leaks out in about a year after market introduction. In our data, we measure the time between market introduction and imitation on the market. Since firms need time to implement the acquired knowledge and bring the resulting imitation to market, time to imitation is conceptually somewhat longer than the time to leaking product specifications. Our data shows a mean time to imitation of about 19 months on average.

Table II. Speed of Imitation

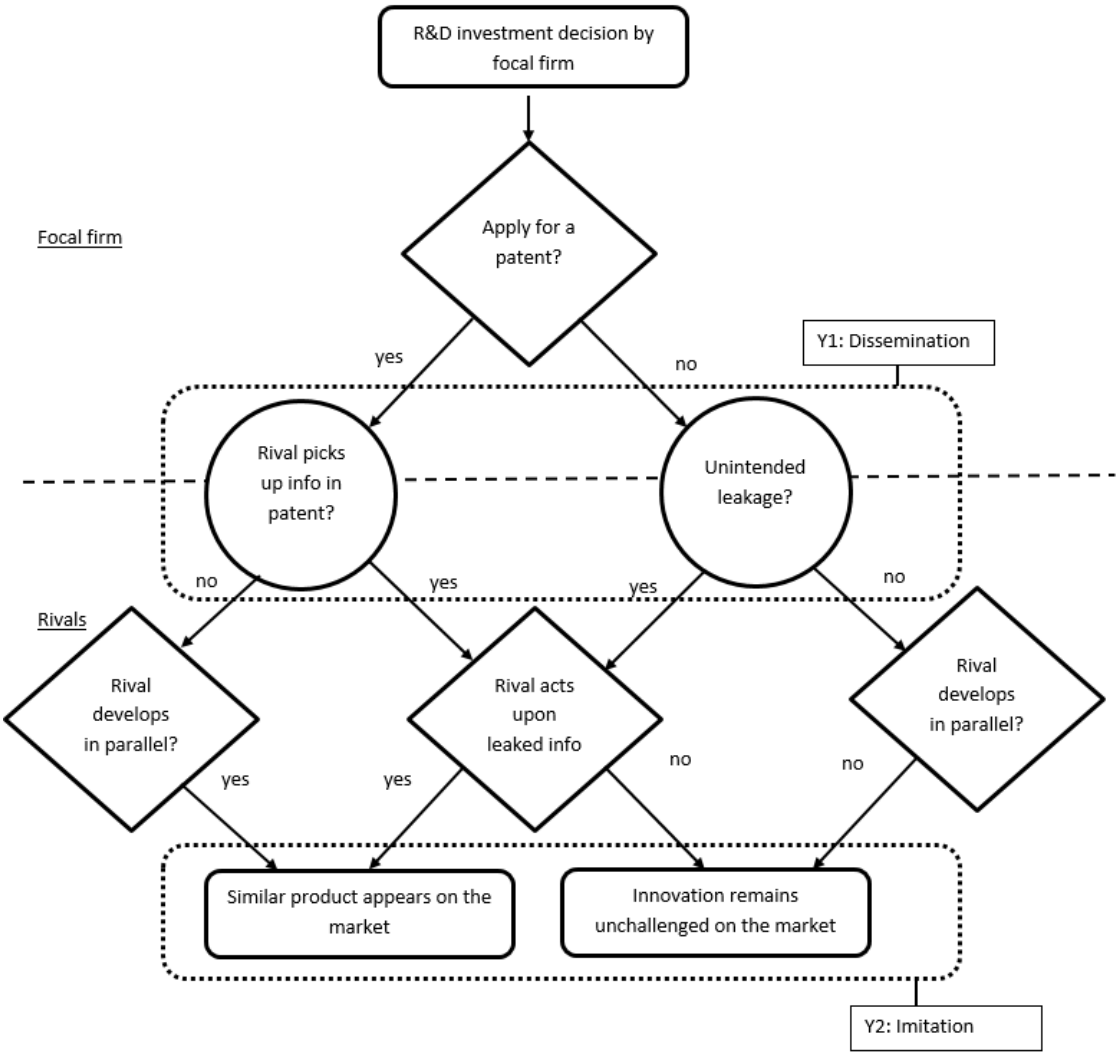
Sector/Months	A. Less than 6	B. 6 to 12	C. 12 to 18	D. 18 and more	Total	Mean
Primary	3	3	8	4	18	12.28
Secondary	3	4	13	24	44	23.09
Tert. & Quat.	5	7	9	14	35	17.29
Total	11	14	30	42	97	18.98

Hereafter the two dependent variables concerning the events of imitation and R&D investment decision leakage as well as the independent variables considered as potential determinants in the process are described. Next to pretesting of the regular survey, the additional questions regarding imitation and dissemination were pre-tested by presenting them to (R&D) managers of several R&D active firms. The questions from Mansfield (1985) served as initial input for this process. Binary filter questions regarding the occurrence of the events were introduced. The questions about the speed with which the events took place were then only presented to firms for which the events actually occurred. The wording of the survey questions was adapted based on the results from the pre-tests and resulted in a final version after two iterations. The main adaptation concerned a shift of focus from inquiring about one exemplary project/product/process to inquiring about overall firm level overages of the speed of the events. Also, the final survey questions included ‘don’t know’ options in order to improve accuracy of the actual response and in order not to introduce unnecessary response burden.

III.B. Dependent Variables – Imitation and Diffusion

Variable IMITATION indicates whether a company's products or processes were imitated in the past 10 years. R&D DIFFUSION indicates if a company's R&D decisions were ever leaked to competitors. Figure II depicts the process that precedes potential imitation. First, after the focal firm has made an R&D development decision, it has to decide whether it applies for patents on the resulting inventions. Second, the information on the focal firm's R&D could diffuse to rivals in basically three ways. If the focal firm decided to apply for a patent, rivals could pick up the information once the patent document gets disclosed. If the focal firm did not apply for a patent on the invention, the information could still unintendedly get leaked to rivals, e.g. when a trade secret gets infringed (as, for example, could happen due to (high) employee turnover, informal meetings, etc.), or be purposely be disclosed by e.g. participation in conferences and trade fairs. Finally, the rivals could take action based on the diffused information. If at least one rival decides to imitate or to invent-around the patent, after a certain period of time (time to imitation, time to invent-around), a similar product appears on the market. If the rivals, given the diffused information and potential property rights, decides not to engage in imitative R&D, the innovation will remain unchallenged on the market.

Figure II. Knowledge Leakage, Imitation and the Patent System



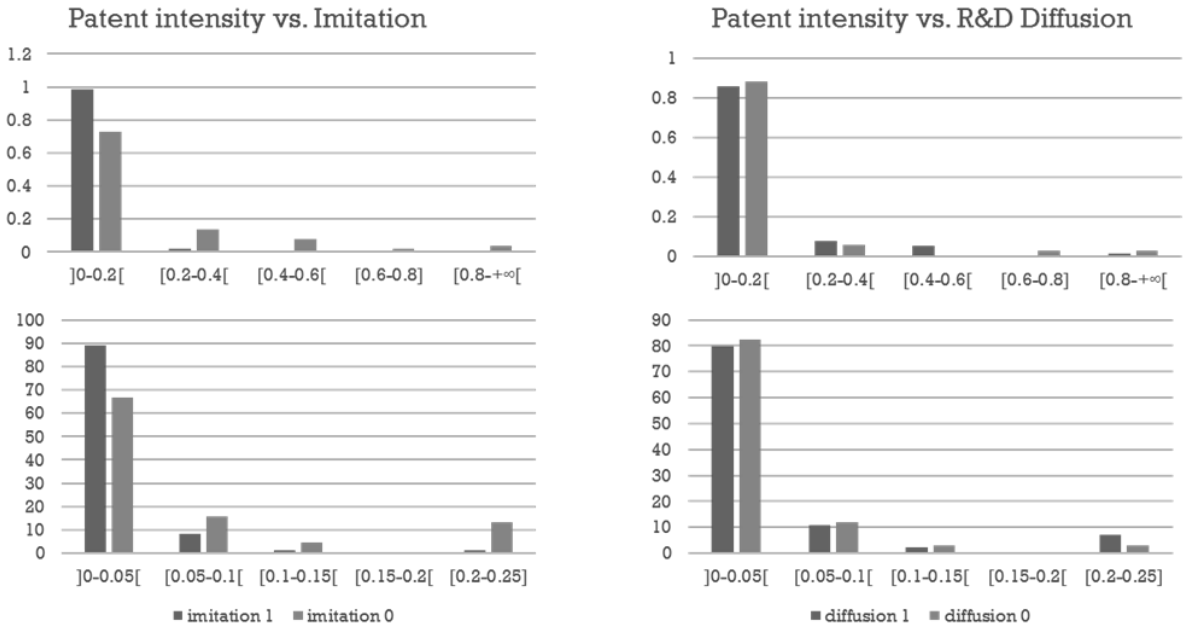
III.C. Independent Variables: Drivers of Imitation and Knowledge Dissemination

Patent stock (PS) for firm i in year t, was retrieved from Patstat by applying the following formula.

$$PS_{it} = (1 - \delta)\, PS_{it-1} + patent\ applications\ at\ family\ level_{it}$$

δ, the constant knowledge depreciation rate, is set to 15% as is standard in the literature (e.g. Griliches & Mairesse, 1984; Hall, 1990; Czarnitzki & Kraft, 2010). All, worldwide, patent applications were retrieved from patstat based on name matching of the applicant text field. The patent applications are aggregated at the family level to obtain unique inventions. PATENT INTENSITY further scales the patent stock by the number of employees. The patent intensity enters the specifications with base year 2013 as to consider all patents relevant to the considered period of potential imitation (2003-2013). Figure III descriptively depicts how the PATENT INTENSITY relates to the two outcome variables. The PATENT INTENSITY is more skewed to the right for the non-imitated part of the sample. No substantial differences exist however when splitting the distribution by R&D Diffusion.

Figure III. Distributions of PATENT INTENSITY for Strictly positive values - splitting by IMITATION and R&D DIFFUSION.



Apart from the patenting behavior there are several firm level characteristics that can influence the chances a firm gets confronted with imitation and knowledge dissemination. Since these other drivers of imitation are potentially correlated with the patenting strategy of a firm it is important to control for them in our analyses as otherwise they might constitute an omitted variable bias. As these drivers of imitation are currently understudied in literature we address them here below.

While ample studies investigate the link between firm growth and innovation (e.g. Coad & Rao, 2008; Goedhuys & Veugelers, 2012; Audretsch et al. 2014), not much has been said about how and why firms are being confronted with imitation. Also, the broad literature on spillovers and growth remains largely silent about possibly induced imitation. Hereunder we consider firms' industry characteristics, R&D, and export profile as drivers of imitation and knowledge dissemination.

R&D is the most important input in creating new, patented, products and processes. Given the high-risk profile of R&D investments companies that make these investments assume that in the end their efforts will result in higher mark-ups (Cohen & Klepper, 1996; Czarnitzki & O'Byrnes, 2007). Since R&D produces mainly knowledge, which is a public good, these investments might suffer from negative externalities or spillovers, though. We measure R&D INTENSITY as intramural R&D spending per employee in 2013 in thousands of euros. EXTERNAL R&D measures the extramural R&D expenditures per employee a company had in 2013 in thousands of euros.

For manufacturing industries it has been shown that basic research has a productivity impact. Mansfield (1980) shows that the impact of basic research on total factor productivity is not only positive but also larger than the same expenditure on applied R&D (Diamond, 2003). Moreover, investments in basic research can provide companies with a longer lasting

technological advantage over competitors since the results from this type of research are not as directly applicable as output from applied research and development investments. Since more prerequisite knowledge is required to interpret and further apply basic research results, potential imitators of the products incorporating these basic technologies might be impeded in their efforts or might even be inhibited to start imitative R&D. Variables DEVELOPMENT PCT., APPLIED R&D PCT., and FUNDAMENTAL R&D PCT. are the percentages of their intramural R&D budget companies spend on respectively development, applied research, and fundamental research.

Exporting can make firms benefit from a larger market to sell their products and it also provides the occasion to scout for new inventions in foreign markets (Barrios et al., 2003). The idea of learning-by-exporting is a highly discussed topic by economists. Salomon & Jin (2010) mention that exporting firms that lack a decent technology or know-how may benefit the most from this kind of learning as foreign markets put technologies at their disposal which they can adapt to improve their business operations. However, diffusion of existing technologies tends to happen faster when firms are clustered in the same area (Pederson, 1970). This is especially true for high-tech industries (Audretsch & Feldman, 1996). Exporting firms have their products present on a larger set of geographical markets. They might also decide to have a local base of operations on the export market. Thus, while exporting might provide firms with the opportunity of learning-by-exporting, when a firm has a technology that is better than that of the export market it might suffer from imitation due to exporting. Literature does not yet provide any empirical evidence regarding this matter. The variable EXPORT measures the percentage of sales in the survey period that was not generated domestically (within Belgium).

The dependent survey variables are measured in the survey's base years and act as proxies for the companies' innovation profile during the period in which the reported imitation took place.

Given the persistency of R&D and innovation (Peters, 2009) we reason these proxies are sufficiently strong.

Further, general controls on firm size, measured by EMPLOYMENT, and AGE are available. The data is also further partitioned into sectors. Based on NACE2-codes we construct a set of sector dummies (SECD*). Patents' effectiveness as a mean to enhance appropriation, or forestall imitation, varies across firms and technology fields (Mansfield, 1986; Levin et al., 1987; Cohen et al., 2000). Especially firms in industries that are reliant on technologies based on heavily codified knowledge might suffer from imitation (Teece, 1986). Patents are therefore more frequently used in some industries than others. Descriptive statistics can be found in Table III.

III.D. Instrumental Variables

In what follows we will instrument the R&D DIFFUSION variable to account for possible endogeneity in regressions on imitation. Given that we conjecture that knowledge diffusion influences imitation in a staged process and potential unobserved important drivers of imitation could correlate with knowledge diffusion, we should consider potential omitted variable bias. The instruments of choice are an industry average of R&D DIFFUSION at the 3 digit NACE level (AVG. R&D DIFFUSION) and the number of EXTERNAL CONSULTANTS working on the companies' R&D activities. The industry average, we argue, has an influence on the R&D investment decision leakage at the firm level through industry specific diffusion channels but not on imitation once we accounted for the other drivers of imitation at the firm level. External R&D consultants get to know R&D projects a company is conducting early on; it is however reasonable they are exempt from imitating by means of, for

example, non-compete clauses in the contract. The instruments will also serve as exclusion restrictions in a recursive bivariate estimation.

Table III. Descriptive Statistics for Estimation Sample of 423 Observations

VARIABLE	Variable description	μ	σ	Min	Max
IMITATION (DUMMY)	Indicates whether a company was confronted with initiation of its products and processes (in the past 10 years)	0.46	0.50	0	1
R&D DIFFUSION (DUMMY)	Indicates whether a company was ever confronted with leakage of its R&D investment decisions	0.65	0.48	0	1
EXPORT	Percentage of turnover generated from exports outside Belgium	47.14	37.26	0	100
FUNDAMENTAL R&D PCT.	Percentage of intramural R&D expenditures spend on fundamental research	8.95	18.84	0	100
APPLIED R&D %.	Percentage of intramural R&D expenditures spend on applied research	47.83	35.18	0	100
DEVELOPMENT %.	Percentage of intramural R&D expenditures spend on development	43.22	35.46	0	100
R&D INTENSITY	Intramural R&D expenditures / # employees	29.81	41.65	0.0597	389
EXTERNAL R&D	Extramural R&D expenditures / # employees	3.08	13.04	0	157
PATENT INTENSITY	Depreciated patent stock per employee	0.02	0.09	0	0.92
AGE	2013- year of foundation	20.27	15.21	0	88
EMPLOYEMENT	# employees	45.71	53.03	1	233
AVG. R&D DIFFUSION	Industry average of R&D DIFFUSION at the 3-digit nace sector level	0.65	0.16	0	1
EXTERNAL CONSULTANTS	Number of external consultants working on the firm's R&D	0.89	2.43	0	25

Table IIIB. Sector Distribution for Sample of 423 Observations

Sector	SECTOR DESCRIPTION	N	R. Freq
Sector1	Food, beverage, tobacco	22	0.05
Sector2	Textile, clothing and leather industry	30	0.07
Sector3	Manufacture of cokes, chemicals, pharmaceuticals, rubber and plastic	52	0.12
Sector4	Manufacture basic and fabricated metal products	22	0.05
Sector5	Manufacture of electrical, electronic and optical products	28	0.07
Sector6	Manufacture, repair and installation of machinery, equipment, tools and transport	42	0.10
Sector7	Construction and civil engineering	66	0.16
Sector8	Wholesale	34	0.08
Sector9	Telecommunication, software design and programming, computer-consultancy and information services	89	0.21
Sector10	Architects and engineering, R&D and management consulting	30	0.07
Rest category		8	0.02

Table IV. Bivariate Correlations for Estimation Sample of 423 Observations

Pairwise correlation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. IMITATION	1										
2. R&D DIFFUSION	**0.17**	1									
3. EXPORT	**0.19**	0.06	1								
4. APPLIED R&D %	-0.02	0.02	0.02	1							
5. DEVELOPMENT %	0.09	-0.04	0.02	**-0.86**	1						
6. R&D INTENSITY	-0.05	**0.11**	-0.06	-0.00	-0.01	1					
7. EXTERNALR&D	-0.04	0.07	-0.09	0.02	-0.02	**0.55**	1				
8. PATENT INTENSITY	**-0.13**	0.01	-0.04	-0.01	0.01	0.08	-0.04	1			
9. LNAGE	**0.20**	0.02	**0.15**	-0.05	0.06	**-0.44**	**-0.23**	**-0.10**	1		
10. LNEMPLOYMENT	**0.21**	0.00	**0.27**	**-0.13**	**0.17**	**-0.49**	**-0.27**	**-0.21**	**0.56**	1	
11. EXT. CONSULT	0.06	**0.15**	0.04	-0.01	-0.01	**0.20**	0.07	-0.00	**-0.10**	0.07	1
12. μ(R&D DIFFUSION)	**0.13**	**0.32**	**0.16**	-0.01	0.03	**-0.10**	-0.04	0.07	**0.17**	**0.12**	0.02

(Notes: correlations in **bold** are significant at the 5pct. Level)

III.E. Estimation

As the dependent variables are binary we estimate probit models to take into account this property of the data. The initial estimations are univariate in the sense that we estimate the equations for R&D investment diffusion and imitation probability separately where we take up the R&D investment decision leakage variable as an explanatory variable in the imitation equation. To consider possible endogeneity of the R&D DIFFUSION variable, we further estimate a recursive bivariate probit model (Greene, 1998; Greene, 2003) where we use the industry average of the investment decision leakage variable and the number of external R&D consultants as exclusion restrictions for the model to be identified. Finally, in an instrumental variables probit regression we instrument R&D DIFFUSION with the number of external consultants and the industry average of R&D investment decision leakage. This approach

allows to inspect the validity of the instrument by means of a test of overidentifying restrictions following Lee (1992).

IV. RESULTS

Table V contains the results from univariate probit estimations. The initial specification on IMITATION (1) only includes PATENT INTENSITY and general firm level controls. In line with H1, PATENT INTENSITY shows up negative and marginally significant. The initial specification on R&D DIFFUSION (2) additionally includes the industry averaged R&D DIFFUSION. AVG. R&D DIFFUSION is the only variable showing up as significant in the regression. (3) adds the R&D DIFFUSION variable to the initial specification on IMITATION (1), the magnitude and significance of the PATENT INTENSITY coefficient goes up. Also, in line with H3, R&D DIFFUSION has a positive and significant coefficient. Specifications (4) - (6) stack the other drivers on top of the variables used in (1) - (3). The results on PATENT INTENSITY and R&D DIFFUSION are robust when including these drivers. Moreover, the results on the drivers are positive if significant, meaning they indeed impact the chances of being imitated positively. A higher share of exports in the turnover increases the probability to be imitated, as does a higher share of applied research and development in the total R&D. There does not seem to be a R&D intensity effect on imitation however. Regarding H2 we cannot find statistically significant evidence of patents facilitating the dissemination of R&D (findings).

Table VI report the results from a recursive bivariate estimation of the equations together with the results from an instrumental variables probit regression. The full specification single equations probits are again shown as a means of comparison. AVG. R&D DIFFUSION and EXTERNAL CONSULTANTS are used as an exclusion restriction for the bivariate model to be identified. A test on the significance of the rho parameter turns out negative and suggests the equations might as well be estimated separately as there is no significant error term

correlation. A test of overidentifying restrictions following Lee (1992) does not reject the validity of the instruments. A Wald test after the IV probit estimation also cannot reject exogeneity of R&D DIFFUSION in the IMITATION equation. The results are generally robust over the different estimations, except for R&D DIFFUSION which gets slightly less significant in the IV probit.

Table V. Single Equation Probit Estimations

b/(se)	(1) IMIT-ATION	(2) R&D DIFFUSION	(3) IMIT-ATION	(4) IMIT-ATION	(5) R&D DIF-FUSION	(6) IMIT-ATION
EXPORT PCT.				0.005***	0.000	0.005**
				(0.002)	(0.002)	(0.002)
APPLIED R&D PCT.				0.010**	-0.003	0.011***
				(0.004)	(0.004)	(0.004)
DEVELOPMENT PCT.				0.011***	-0.005	0.012***
				(0.004)	(0.004)	(0.004)
R&D INTENSITY				0.003	0.006**	0.002
				(0.002)	(0.002)	(0.002)
EXTERNAL R&D				-0.001	0.009	-0.002
				(0.006)	(0.010)	(0.006)
PATENT INTENSITY	-2.779*	-0.307	-3.130**	-3.123*	-0.179	-3.429**
	(1.482)	(0.768)	(1.583)	(1.603)	(0.764)	(1.659)
Log AGE	0.202**	-0.023	0.199**	0.260**	0.05	0.247**
	(0.098)	(0.100)	(0.099)	(0.102)	(0.105)	(0.103)
Log EMPLOY-EMENT	0.139**	-0.021	0.141**	0.125*	0.056	0.118*
	(0.064)	(0.067)	(0.064)	(0.070)	(0.073)	(0.071)
R&D DIFFUSION			0.476***			0.465***
			(0.135)			(0.138)
AVG. R&D DIFFUSION		3.144***			3.185***	
		(0.498)			(0.510)	
Sector dummies	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
constant	-1.269**	-1.261**	-1.535***	-2.681***	-1.560**	-2.907***
	(0.548)	(0.635)	(0.548)	(0.681)	(0.731)	(0.684)
Pseudo R2	0.067	0.089	0.088	0.102	0.111	0.122
#obs	423	423	423	423	423	423
Wald	38.845	48.685	51.536	59.691	60.818	71.127
Sig(Wald)	0	0	0	0	0	0
Joint Sig. Sectors	0.488	0.999	0.444	0.403	0.999	0.379

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.)*

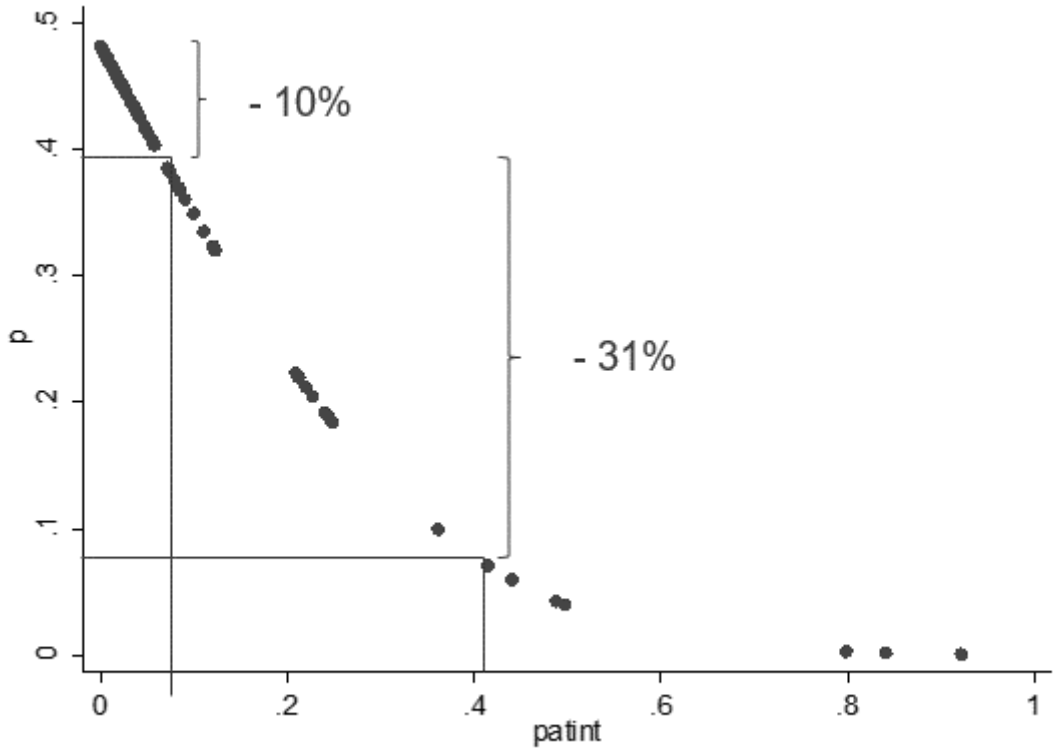
Table VI Robustness Checks: Bivariate Probit and IV Probit

	Single equation probits		Bivariate probit		IV probit
b/(se)	R&D DIFFUSION	IMITATION	R&D DIFFUSION	IMITATION	IMITATION
EXPORT PCT.	0.000 (0.002)	0.005** (0.002)	0.000 (0.002)	0.005** (0.002)	0.005** (0.002)
APPLIED R&D PCT.	-0.003 (0.004)	0.011*** (0.004)	-0.003 (0.004)	0.011*** (0.004)	0.011*** (0.004)
DEVELOP-MENT PCT.	-0.005 (0.004)	0.012*** (0.004)	-0.004 (0.004)	0.012*** (0.004)	0.013*** (0.004)
R&D INTENSITY	0.006** (0.002)	0.002 (0.002)	0.005* (0.003)	0.002 (0.002)	0.002 (0.002)
EXTERNAL R&D	0.009 (0.010)	-0.002 (0.006)	0.004 (0.009)	-0.002 (0.006)	-0.002 (0.006)
PATENT INTENSITY	-0.179 (0.764)	-3.429** (1.659)	-0.267 (0.771)	-3.400** (1.638)	-3.458** (1.663)
Log AGE	0.05 (0.105)	0.247** (0.103)	0.070 (0.106)	0.235** (0.104)	0.236** (0.105)
Log EMPLO-YMENT	0.056 (0.073)	0.118* (0.071)	0.001 (0.076)	0.111 (0.071)	0.110 (0.072)
R&D DIFFUSION		0.465*** (0.138)		0.772*** (0.360)	0.856** (0.420)
AVG. R&D DIFFUSION	3.185*** (0.510)		3.183** (0.513)		
EXTERNAL CONSUL-TANTS			0.150*** (0.051)		
Sector dummies	Incl.	Incl.	Incl.	Incl.	Incl.
Constant	-1.560** (0.731)	-2.907*** (0.684)	-1.483** (0.769)	-3.005*** (0.681)	-3.131*** (0.637)
N	423	423	423		423
Wald	60.818	71.127	118.607		53.28
Sig(Wald)	0.000	0.000	0.000		0.000
Joint Sig. Sectors	0.999	0.379	0.9319		0.4088
Rho			-0.2170		

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.. Test of overidentifying restrictions does not reject validity of the instruments. In the bivariate estimation, the rho parameter is negative but insignificant. For the IV probit second stage results are shown, R&D DIFFUSION is instrumented by AVG. R&D DIFFUSION and EXTERNAL CONSULTANTS. A test of over identifying restrictions, following Lee (1992) does not reject the validity of the instruments: 0.044 Chi-sq(1) P-value = 0.8341. A Wald test after the IV probit estimation also cannot reject exogeneity of R&D DIFFUSION in the IMITATION equation: chi2(1) = 1.18, Prob > chi2 = 0.2780)*

The size of the effects can be gauged by looking at the change in the predicted probabilities given a certain change in an independent variable keeping the other independent variables fixed at their mean. We calculate the marginal effect as a discrete jump from one variable value to another. As such, based on the bivariate estimation, changing the patent intensity from 0 to the mean of the strictly positive values decreases the predicted probability of being imitated by little over 10 percent. Going from the mean patent intensity to the 95th percentile decreases the predicted probability by about 30 percent.

Figure III Change in predicted probabilities for discrete jumps in patent intensity



Switching the R&D DIFFUSION variable from zero to one increases the predicted probability with about 17 percent, meaning that companies that leak important R&D investment decisions at some point are 17 percent more likely to be hit by imitation later.

V. ADDITIONAL ANALYSES

To identify from which part of the patent intensity distribution our found effects stem from, we re-ran the (single equation) analysis, replacing the continuous patent intensity variable with 3 dummy variables. Results can be found in Table VII.

PATENT DUM.1 is an indicator variable of zero patent intensity. PATENT DUM.2 takes on the value one when a patenting company had a patent intensity lower than the mean patent intensity of patenting companies. PATENT DUM.3 completes the partitioning by indicating patenting companies that had a patenting intensity larger than the mean patent intensity of patenting companies. Our results suggest the effects in the main analysis are driven by firms heavily engaged in patenting, i.e. having patent intensities larger than the mean of the patenting companies.

The share of patented inventions would better capture the patenting intensity of the firms. The effect of such a variable on leakage and imitation propensities would have a cleaner interpretation because it has a more direct link with the outcome variables; more leakage and less imitation could then (better) be attributed to more patents on the underlying inventions. However, as we do not have a measure for number of (patentable) inventions, in our analysis we are restricted to using the company patent stock as the regressor of interest. Here we try to take into account the above consideration by including a more direct control for the number of patentable inventions. From CIS data (CIS2013)[6] we added a variable indicating whether the firm had any worldwide novelties in the past three years (MKTNOVEL). The reasoning here being that such innovations, on average, incorporate more patentable inventions given the firm's industrial sector of activity. The regression results (see Table VIII) showed that

[6] The Community Innovation Survey (CIS) is conducted by the Centre for Research & Development Monitoring (ECOOM) on behalf of the Flemish government on a bi-annual basis.

worldwide market novelties are indeed positively related to the probabiltiy of imitation and the results on the patenting variable were robust when adding it to the specification. Furthermore, when stacking our proxy measures for the companies' innovation profile into the specification, the effect of MKTNOVEL becomes insignificant and the need for such a specific proxy number of patentable inventions less necessary.

Table VII. Additional analysis - Single Equation Probit Estimations with Patenting Dummies

b/(se)	(1) IMIT-ATION	(2) R&D DIF-FUSION	(3) IMIT-ATION	(4) IMIT-ATION	(5) R&D DIF-FUSION	(6) IMIT-ATION
EXPORT PCT.				0.005***	0.000	0.005**
				(0.002)	(0.002)	(0.002)
APPLIED R&D PCT.				0.01**	-0.003	0.01**
				(0.004)	(0.004)	(0.004)
DEVELOPMENT PCT.				0.011***	-0.004	0.012***
				(0.004)	(0.004)	(0.004)
R&D INTENSITY				0.003	0.004*	0.002
				(0.002)	(0.003)	(0.002)
EXTERNAL R&D				0.000	0.006	-0.001
				(0.006)	(0.009)	(0.006)
PAT DUM.1	-0.302*	-0.067	-0.279	-0.253	-0.056	-0.233
	(0.168)	(0.182)	(0.170)	(0.170)	(0.184)	(0.172)
PAT DUM.3	-0.712**	-0.017	-0.722**	-0.729**	0.044	-0.735**
	(0.325)	(0.338)	(0.326)	(0.333)	(0.341)	(0.333)
Log AGE	0.200**	0.026	0.201**	0.256**	0.068	0.247**
	(0.098)	(0.103)	(0.100)	(0.102)	(0.106)	(0.103)
Log EMPLOY-MENT	0.126*	-0.058	0.13**	0.115	0.01	0.11
	(0.065)	(0.070)	(0.066)	(0.071)	(0.077)	(0.072)
R&D DIFFUSION			0.458***			0.448***
			(0.134)			(0.138)
EXTERNAL CONSUL-TANTS		0.172***			0.142**	
		(0.057)			(0.058)	
AVG. R&D DIFFUSION		3.17***			3.181***	
		(0.509)			(0.518)	
Sector dummies	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
constant	-1.1*	-1.411**	-1.399**	-2.517***	-1.549**	-2.78***
	(0.563)	(0.684)	(0.563)	(0.696)	(0.778)	(0.699)
Pseudo R2	0.066	0.115	0.086	0.099	0.128	0.118
#obs	423	423	423	423	423	423
Wald	38.385	63.091	50.185	58.028	70.023	68.712
Sig(Wald)	0	0	0	0	0	0
Joint Sig. Sectors	0.469	1	0.443	0.355	1	0.352

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct., * less than 10 pct; reference category for patent intensity partitioning is PAT DUM.2, i.e. companies that have a positive patent intensity smaller than the mean of the strictly positive patent intensities.)*

Table VIII. Additional analysis - Single Equation Probit Estimations Including Market Novelties Variable

b/(se)	(1) IMIT-ATION	(2) R&D DIF-FUSION	(3) IMIT-ATION	(4) IMIT-ATION	(5) R&D DIF-FUSION	(6) IMIT-ATION
EXPORT PCT.				0.005**	0.000	0.004**
				(0.002)	(0.002)	(0.002)
APPLIED R&D PCT.				0.010**	-0.004	0.010**
				(0.004)	(0.004)	(0.004)
DEVELOPMENT PCT.				0.011***	-0.005	0.012***
				(0.004)	(0.004)	(0.004)
R&D INTENSITY				0.003	0.004*	0.002
				(0.002)	(0.003)	(0.002)
EXTERNAL R&D				0.000	0.006	-0.001
				(0.006)	(0.009)	(0.006)
PATINT	-3.166**	-0.391	-3.472**	-3.436**	-0.276	-3.712**
	(1.603)	(0.791)	(1.654)	(1.696)	(0.789)	(1.719)
MKTNOVEL	0.397**	0.192	0.368**	0.302	0.171	0.289
	(0.181)	(0.200)	(0.183)	(0.188)	(0.204)	(0.189)
I(Missing)	-0.1	-0.362**	-0.061	-0.121	-0.379**	-0.078
	(0.160)	(0.174)	(0.162)	(0.164)	(0.176)	(0.166)
Log AGE	0.191*	-0.033	0.195*	0.245**	0.005	0.240**
	(0.101)	(0.107)	(0.102)	(0.105)	(0.110)	(0.105)
Log EMPLOY-MENT	0.108	-0.111	0.115*	0.097	-0.047	0.096
	(0.066)	(0.072)	(0.067)	(0.072)	(0.078)	(0.073)
R&D DIFFUSION			0.441***			0.441***
			(0.136)			(0.140)
EXTERNAL CONSUL-TANTS		0.169***			0.140**	
		(0.056)			(0.057)	
AVG. R&D DIFFUSION		3.461***			3.513***	
		(0.527)			(0.540)	
Sector dummies	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
constant	-1.057*	-0.698	-1.361**	-2.417***	-0.727	-2.702***
	(0.583)	(0.682)	(0.589)	(0.714)	(0.769)	(0.721)
Pseudo R2	0.081	0.137	0.099	0.112	0.149	0.129
#obs	423	423	423	423	423	423
Wald	47.27	75.173	57.852	65.251	81.721	75.332
Sig(Wald)	0.000	0.000	0.000	0.000	0.000	0.000
Joint Sig. Sectors	0.428	0.995	0.398	0.353	0.994	0.338

*(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct., * less than 10 pct; I(missing) is an indicator variable on the missing-ness of the MKTNOVEL variable which was imputed to 0 if missing, which is reasonable because the firms with imputed values stem from the random part of the CIS sample, meaning they either did not innovate in the past or were not yet part of the fixed, innovating, part of sample)*

VI. DISCUSSION AND CONCLUSION

With regard to the appropriation function of patents, we find evidence supporting the view that patents have the desired effect of lowering the probability to get imitated, also for SMEs. Though we did not establish any causal effect due to the limitations of the data, our results are suggestive of patents being good countermeasures to imitation. Indeed within our sample of firms, those having higher patent intensities have lower predicted imitation probabilities. While we control for relevant characteristics of the firms' innovation profile one might be concerned with a potential reverse causal interpretation where companies hit by imitative offerings increase their patenting activity in reaction. We argue, this reasoning, while valid, should not form a major point of concern. In an additional robustness check (results not reported) we further dropped the patents applied for in the period overlapping with the surveyed period from the patent stock and still find results significant at most at the 10 pct. level. This should, however, not come as a surprise as most of the imitation happens rather fast, i.e. in less than about one and a half year. Protection from imitation might be of particular importance when companies are very export intensive or if their inventions rely on applied research and development as the evidence supports these companies are especially prone to imitation. Given the potential deficiencies patents cause from a social welfare perspective (e.g. static monopoly rents, dynamic inefficiencies in innovation intensity, …) government should be aware that a well-behaved patent protection function in terms of imitation could still potentially lead to a suboptimal outcome in terms of social welfare. Our analysis also points to the fact that R&D investment decisions are not more likely to be leaked if a company patents its inventions more intensely. While the dissemination of R&D findings is not measured directly by our data we conjecture that if information regarding the R&D investment decision is not leaked more frequently after taking out patents, R&D findings are most probably also not. As the investment

decision captures the basic ideas of what is to be carried out during the R&D efforts, companies who are able to keep the investment decision secret will more likely also be able to keep their findings secret. The fact that we find that there is no effect of applying for patents on diffusion of information can be seen in the light of a selection amongst patented inventions. It could also partially be attributed to the effective use of (juridical) jargon to conceal research findings as much as possible within the patent documents.

Our results are driven by firms heavily engaged in patenting, i.e. having a patent intensity larger than the mean of the patenting firms. These results suggest that especially firms that consistently try to protect their inventions by means of taking out patents, benefit from protection from imitation. However, this result could also be indicative of the effectiveness of patent fencing strategies, a strategy where a firm takes out a series of patents on near substitutes of the original invention. The protection from invent-around imitation that these strategies try to achieve also reduces follow-on innovation by competitors.

Regarding the driving factors of imitation, we find some evidence of imitation due to exporting. The analysis points out that companies with high export shares seem to be hit more by imitative offerings. Also, companies heavily invested in development efforts as opposed to basic and, to a certain extent, applied research are more prone to being imitated on the market. On one hand, these results have implications for industries where imitation has direct negative consequences in terms of appropriability of the return on R&D[7]. A growth strategy based on exporting newly developed products (and processes) which required no preceding basic research efforts might then be out of balance. When companies do pursue such a strategy, they will want to consider whether they will recoup their development investments given the higher

[7] For example, in certain specific industries such as computers, software, and semiconductors, when innovation is sequential and complementary, firms might, however, suffer from patent protection and benefit from imitation (Bessen and Maskin, 2009).

probabilty to be imitated. Leakage of (early stage) R&D investment decisions and imitation appear to be part of a staged process. Companies should thus also be aware that an early leaking of info about their R&D investments could increase the probability to get imitated later. On the other hand policy makers can be informed by the evidence we gathered regarding the drivers of imitation. Especially in small export dependent innovative economies like Flanders it is of importance to balance the growth strategy for the economy. Trying to grow the economy by stimulating exports and at the same time subsidizing pure development investments might work counter effective. To account for the interaction between both drivers the timing of the use of these policy instruments might be of importance.

This study aimed to assess the functioning of the patent system in terms of the protection it should provide against imitation and the dissemination of R&D findings it should facilitate. Patenting inventions can bring relief by lowering the probability to get imitated. Imitation also appears as a staged process where early leakage of investment decisions impacts chances of being imitated later. From the perspective of both firms and governments, imitation is the flip side of the coin of innovation. It is therefore important to get a grasp on what its determinants are. The results indicate that especially export intensity, basicness of conducted R&D, and the use of patents are of importance in this respect. A larger geographical market to sell products comes with an increased visibility of the companies' innovations which in turn could lead to imitation, especially when the new products required no upfront basic research investments.

Hall et al. (2013) find that in the UK only approximately 4 % of innovators also patent, stressing that most firms find informal ways of protecting their intellectual assets more important. Our analysis could therefore be complemented by including other appropriabilty mechanisms such as secrecy and lead time advantages in the analysis (see e.g. Arundel, 2001; Hall et al., 2014). Unfortunately, this information was not available in the Flemish R&D survey

of 2014. However, Graham & Hegde (2015) find that small U.S. inventors under the American Inventor's Protection Act (AIPA) are not (often) using the "opt out" option and thereby foregoing pre-grant secrecy to protect their most important inventions. Therefore, the issue might not be that severe for SMEs.

Our study was limited by the response to the survey questions on the speed of imitation and knowledge dissemination. Sufficiently strong patent protection should allow innovators enough time to recoup their R&D investments, but will probably not prevent imitation from occurring in a 10-year period. Against this backdrop, our binary imitation measure is not fine grained enough to assess the well-functioning of patent system in terms of stalling imitations from coming onto the market. If an imitation occurs too soon for the innovator to be able to recoup his R&D costs and further prevents him from doing so, considerable losses might be incurred. It would therefore be interesting to study the distribution of time to imitation more closely. Patents may well decrease the likelihood of imitation but when they fail to do so they might still provide enough time for the innovator to make the R&D investment break even. Regarding our measurement of R&D investment decision leakage, one could argue that if a firm leaked actual knowledge it probably must have also leaked its decision to invest. As an investment decision contains the basics of the R&D that is to be conducted, it, as such, also contains the basic principles of the knowledge generated. On the contrary, a scenario where a firm leaks only its (basic) investment decision and not the actual generated knowledge is still possible. Therefore, a better 'knowledge leak' variable would only have a subset of positive outcomes as compared to our 'investment decision leak' variable. Furthermore, our empirical setup is limited by the cross-sectional nature of the data and the lack of project level information. Given the correlational nature of the evidence our results should be interpreted with adequate caution. One point of concern, for example, might be possible endogeneity of the

patent intensity variable. To make causal statements one, ideally, would like to observe imitation and the potential determinants multiple times in a panel data structure. Lagging the patent intensity variable could then make the exogeneity assumption more plausible.

Chapter III

New Evidence on Determinants of IP Litigation: A Market-Based Approach[8]

Abstract
We contribute to the economic literature on patent litigation by taking a new perspective. In the past, scholars mostly focused on specific litigation cases at the patent level and related technological characteristics to the event of litigation. However, observing IP disputes suggests that not only technological characteristics may trigger litigation suits, but also the market positions of firms, and that firms dispute not only about single patents but often about portfolios. Consequently, this paper examines the occurrence of IP litigation cases in Belgian firms using the 2013 Community Innovation Survey with supplemental information on IP litigation and patent portfolios. The rich survey information regarding firms' general innovation strategies enables us to introduce market-related variables such as sales with new products as well as sales based mainly on imitation and incremental innovation. Our results indicate that when controlling for firms' IP portfolio, the composition of turnover in terms of innovations and imitations has additional explanatory power regarding litigation propensities. Firms with a high turnover from innovations are more likely to become plaintiffs in court. Contrastingly, firms with a high turnover from incremental innovation and imitation are more likely to become defendants in court, and, moreover, are more likely to negotiate settlements outside of court.

[8] This Chapter is co-authored with Dirk Czarnitzki and currently submitted for journal publication. It has appeared in the MSI and ZEW working paper series.

I. INTRODUCTION

The bulk of economic literature which has focused on patent litigation related the fact of litigation to technological characteristics of the underlying patent (see e.g. Lanjouw and Schankerman, 2001, 2004; Cremers, 2006, 2009; Somaya, 2003, Hall & Ziedonis, 2007; Galasso & Schankerman, 2010, Galasso et al. 2013). In this paper, we take the analysis to the firm level and account for market outcomes of innovation projects. By considering the asymmetric impact market positions regarding imitations and market novelties may have on the propensities of becoming plaintiff or defendant at court, we show that the market valorization of innovations play a significant role in addition to technological characteristics of the challenged intellectual property (IP). We are furthermore able to investigate the occurrence of out of court settlements and retaliation actions in terms of requests for nullification of the underlying IPR. These issues are largely neglected by extant literature.

IP litigation has been regarded as a niche topic in economics in the past. For instance, the number of patent litigation cases compared to the number of issued patents is fairly low. In the United States, for example, 1,706 patent cases were filed at US district courts in 1995. Compared to 114,241 issued patents, the litigation ratio only amounts to 1.5%. By 2005, these numbers, however, had risen to 2706 vs. 165,485 (= 1.6%). According to recent figures (2013), the patent litigation cases peaked at 6,386 (compared to 290,083 patents issued), yielding a litigation ratio of 2.2%. (Sources: USPTO's performance & Accountability Report[9]; US Courts' Judicial Facts and Figures[10]) Even more than the ratios, the absolute numbers show the growing importance of IP litigation: within two decades the number of patent litigation cases has almost

[9] See http://www.uspto.gov/about-us/performance-and-planning/uspto-annual-reports

[10] See http://www.uscourts.gov/statistics-reports/analysis-reports/judicial-facts-and-figures

quadrupled. It is also important to recognize the importance of IP litigation cases for the involved parties. According to PWC (2015) the annual median damage award ranged in the last 20 years between US$ 1.9 million to US$ 17 million (overall median = US$ 5.4 million). In light of the growing number of litigation cases since the 1990s, these numbers unambiguously show the importance of IP. The gravity of the matter becomes apparent when looking at the largest adjudicated damage awards in the last decades. In 2009, the damage award in the case *Centocor Ortho Biotech Inc. vs. Abbott Laboratories* concerning arthritis drugs amounted to US$ 1,673 million, and, in 2007, the case *Lucent Technologies Inc. vs. Microsoft Corporation* concerning MP3 technology amounted to US$ 1,538 million.[11] In addition, plaintiffs and defendants may often settle on their IP disputes. An example where parties settle on a larger scale is Google and Microsoft who settled upon about 20 IP dispute cases in Germany [12]and the United States (October 1st, 2015). A more recent case reported in global news (May, 2016) is Nivdia and Samsung who settled upon all competing patent litigation cases before the U.S. International Trade Commission and U.S. Patent and Trademark Office.[13]

In this paper, we consequently add to the economic literature on patent litigation by taking a somewhat different perspective than the existing studies:

1. The observation that firms battle over bundles of IP rights rather than single patents, for instance, suggests taking the analysis to the firm level rather than the patent level. We thus take portfolio variables at the firm level into account.

[11] Monetary figures adjusted for inflation to 2014 US dollars. The damage awards refer to initial adjudication, i.e. these awards may have been vacated, remanded or reduced, were settled while pending appeal, or are still under appeal.

[12] There is no centralized way to challenge the validity of a European Patent (Infringement is dealt with by the national courts).

[13] As our empirical study is on Belgian data, it seems noteworthy that of course also Belgian firms are involved in litigation cases. Examples are *Lankhorst Composites vs. Samsonite Europe* in 2005, and *Abott Laboratories vs. Janssen Pharma* in 2009.

2. While scholars mostly focused on specific litigation cases at the patent level and related technological characteristics to the event of litigation, the portfolio debate strongly suggests that not only technological characteristics matter, but that the market positions of firms may play a prominent role as well. Therefore, we will add new product sales of firms, obtained from survey data, to our empirical model of litigation.
3. Furthermore, using the sales of innovative products allows to characterize the market position in two ways: first, firms' success with original, novel to the market innovations, and second, firms' positions regarding more imitative and incremental innovations. These asymmetric market positions suggest in turn to differentiate between plaintiffs and defendants in court cases.
4. In addition, survey data also suggests that the analysis of court cases as commonly done in prior literature neglects a large proportion of IP disputes that are settled outside of court.[14] Therefore, the relevance of IP and its enforcement has been largely underestimated in the past. Consequently, we also investigate the occurrence of settlement outside of courts.
5. We can also investigate retaliation actions, that is, nullification suits of IP by defendants against plaintiffs as response to accusation of infringements in court (see e.g. also Schliessler, 2015).
6. Finally, IP disputes take place at a broader level than only patents. According to the US Courts' Judicial Facts and Figures, for instance, 3,169 trademark cases and 3,666 copyright cases were filed with the US district courts on top of the 6,386

[14] A notable exception is Fournier & Zhuelke (1989).

patent cases. Especially the non-negligible number of trademark cases emphasizes that market positions of firms may play an important role in the economic analysis of IP disputes (see point 2 above). In robustness checks we therefore also control for other IPRs than patents.

The main data source consists of the Flemish part of the 2013 Community Innovation Survey which was supplemented with questions on IP litigation. The survey data is linked to patent data collected from the PATSTAT database and additional firm level data from BELFIRST of Bureau van Dijk (the Belgian part of the global Orbis database). The sample comprises innovating firms in the manufacturing and business-relevant service sectors. In contrast to many earlier studies, we can identify which firms filed IP infringement cases and which firms were accused of infringing others' IPRs. In addition, the survey data also allows to investigate which firms settled outside of court. The survey explicitly asked for settlement before firms went to court. Thus, our settlement variable allows to observe IP disputes that could never be detected with administrative data.[15] The three IP dispute variables can be related to commonly used patent characteristics (mainly counts and forward citations, as measure of the patent portfolio value), but also to the market positions of firms with regard to their innovation performance. This comprises the sales of products novel to the market and the sales of other innovative products that are mainly based on imitation. In addition, other variables collected from the survey, such as registrations of trademarks, industrial designs, and copyrights can be used to control for IPRs beyond patents.

[15] Note that settlement e.g. in the Google vs. Microsoft in October 2015 does not refer to outside court settlement. These firms settled on pending court cases. Settling on pending court cases is not considered in our paper. It would be a second stage in an empirical model on suits. For evidence on in-court settlement, see e.g. Cremers and Schliessler (2015) and the references therein.

Our data strongly indicates the importance of outside of court settlement for an analysis of IP infringement. About 8% of the companies were involved in a court case whereas nearly as much, 7%, made out of court settlements. Our results indicate that when controlling for the effects of the importance and quality of a firms' IP portfolio, the composition of turnover in terms of innovations and imitations has additional explanatory power regarding litigation propensities. Firms with a high turnover from innovations are more likely to become plaintiffs in court. Contrastingly, firms with a high turnover from imitation and incremental innovation are more likely to become defendants in court, and, moreover, are more likely to negotiate settlements outside of court. The market at stake also seems to play a role in determining firms' propensity to subsequently request nullification of the IP they are accused of infringing upon, i.e. high-volume imitators are more likely to request nullification of the original patent.

The remainder of this paper is structured as follows. Section 2 briefly summarizes the related literature on the determinants of patent litigation, and discusses the development of hypotheses to be tested. In section 3 the data, variables and their descriptive statistics are presented and discussed Section 4 summarizes and discusses the results of the regression analysis. Section 5 concludes.

II. RELATED LITERATURE ON THE DETERMINANTS OF (PATENT) LITIGATION

Intuitively one can expect a positive link between litigation propensity and values at stake. A patent owner may earn monopoly profits in a market that is protect by a patent. If, however, a competitor infringes the patent and competes with the patent owner, both would make duopoly profits. It thus depends on the expected gains from a law suit versus forgone profits whether a patent owner sues a potential infringer. The expected gains from the law suit

depend on the expected damage compensation (which will be largely determined by the forgone profits due to infringement) that the plaintiff may get in case of a successful lawsuit and the trial cost, such as court fees, attorney cost, fees for hearing witnesses, and the expected likelihood to win the case. The latter might not be obvious, as some patents may have been granted erroneously by the patent office and competitors also try to "invent around" patented technologies.

Given these tradeoffs between expected gains and cost of litigation, the incentive to engage in litigation depends crucially on the product market. The larger the market for the innovation, the larger will be the incentive to engage as plaintiff in a court trial (cf. e.g. Bebchuck, 1984, and Hirshleifer 1991, Hylton 2002, Schliessler, 2015).[16]

These thoughts also apply to the perspective of a defendant, of course. A firm that achieves high sales with imitation might face higher likelihoods of litigation as IP owners may try to enforce their monopoly rights. The potential infringer might then have a high incentive to file a nullification suit against the IP of the plaintiff.

In empirical studies on litigation, the "value at stake" is thus a critical variable. Scholars have often focused on technological characteristics and (possibly poor) economic value proxies of IPRs to explain which intellectual assets may be subject to litigation, commonly using citation based measures to relate the value of a patent to litigation propensity.

Lanjouw & Schankerman (2001, 2003, 2004) study the determinants of patent suits by examining the characteristics of litigated patents and their owners, finding that the value of the patent measured by forward citations and claims increases the likelihood of litigation. For Germany, Cremers (2006, 2009) investigates the incidence of litigation and the determinants of

[16] Hylton (2002) emphasizes in his theoretical model that social welfare would increase if damage compensation would actually be higher than foregone profits, as this deters infringement a-priori.

settlement of patent litigation in court. Similar to Lanjouw & Schankerman, she finds that more valuable patents are more likely to be involved in patent litigation and smaller firms are more likely to be involved in litigation cases. Her measures for patent value are forward citations, number of claims, and patent family size.[17] Somaya (2003) also explains settlement probabilities conditional on being at court. He shows that the likelihood of settlement in court trials of patent disputes decreases with forward citations and self-citations which also points at the fact that firms tend to insist on their property rights when stakes are high.

While these contributions all focus on the incidence of litigation at the patent level, only very few authors have started looking at the likelihood of being involved in litigation at the firm level; thereby focusing on the firms' entire patent portfolio and other firm characteristics. Lerner (1995) shows that new biotechnology firms are less likely to patent in subclasses with many other (rival) patents when their litigation costs are high. "Patenting" should in this context be understood as not developing products in crowded technological domains. He interprets these results by stating that firms are aware of the potential to infringe upon their rivals' patents and that they are willing to take precautions. In their contribution "The Patent Litigation Explosion" Bessen & Meurer (2005) look at patent litigation hazards for public firms in the US. As others, they approximate the value of stakes by forward citations and claims but also use the market value of the whole firm as an additional measure.

Focusing on US semiconductor firms between 1973 and 2001, Hall & Ziedonis (2007) also estimate the probability that firms will be involved in patent lawsuits, either as plaintiffs or as defendants. They find that size, patent stock, and R&D intensity all positively affect the likelihood of litigation. These variables are all expected to correlate positively with values at

[17] Family size refers to the number of jurisdictions in which patent protection has been sought for the same invention.

stake. Comparing their results for semiconductor firms to the broad sample of Bessen & Meurer, they find that the probability of being a defendant for semiconductor firms increases more strongly with a higher level of R&D intensity and size of the firm.

Our paper contributes to the empirical research by measuring the market valuation of firms' innovations more directly. Unlike existing studies, we have information on sales with new products. These can be split into sales with products that are new to the market, i.e. original innovation, and sales with products that are just new to the firm's product portfolio but not new to the market. We refer to the latter as imitation. The central research question addressed in this paper focuses at firm level litigation propensities and can accordingly be summarized as:

RQ. *Does a firm's market position with regard to innovation and imitation matter in triggering litigation suits and/or out of court settlement negotiations?*

We contribute to the literature by investigating whether beyond the technological characteristics of IP, the composition of turnover in terms of innovations and imitations has additional explanatory power regarding litigation propensities. As we can observe in our data whether a company acted as plaintiff or defendant in court proceedings and whether firms settled on IP disputes outside of court, we make the following three hypotheses:

We hypothesize a positive relationship between the sales with market novelties and litigation, as IP owners are more likely to enforce their monopoly right when the patent-protected innovations where successful at the market.

H1. The likelihood that a firm acts as plaintiff in an IP infringement case increases with its sales with market novelties (=innovations).

A firm that generates high sales with products that are just new to its product portfolio but not new to the market might be more at risk to infringe on existing IPRs owned by others, and thus it can be expected that these imitators are more likely to be involved in a litigation suit as defendants.

H2. An imitator will more likely be taken to court in an IP infringement case if the sales it generates from its imitations is higher.

Firms may generally first try to settle outside of court to save the trial cost. Since litigation costs are generally high, uncertain law suits with potentially a large payoff is an option that might only become worthwhile if the value at stake is high. This line of reasoning is also consistent with the high stakes means more litigation argument (Somaya, 2003).

H3. Firms are less likely to negotiate settlement deals outside of court if the sales they generate from either innovations or imitations is higher.

In addition to the main hypotheses stated above, this paper explores the relation between firms' responses to the initial lawsuit and our market value measures of innovation and imitation. Once sued for infringement a firm can question the validity of the supposedly infringed upon IP and ask for so called nullification (see e.g. Farrel & Merges, 2004). This request for IPR nullification can be dependent on technological characteristics of the IP and market valuations thereof. If market value of the challenged IP is high, it is reasonable to expect higher nullification propensities when compared to lower market values. Companies might also be inclined to request invalidations to keep the option open to come up with more follow-on innovations later (see Galasso & Schankerman, 2015). From a firm perspective, this translates into the following hypothesis.

H4. A defendant generating higher sales from imitations is more likely to request nullification of the allegedly infringed upon IPR.

III. METHODOLOGY

III.A. Data – Flemish CIS Survey, PATSTAT & ORBIS

The data set used to conduct the analysis originates from the Flemish Community Innovation Survey , an inquiry about the innovative activity in the Flemish economy carried out biennially since 1993. The CIS methodological standards comprise a stratified random sampling procedure to ensure representativeness of the sample for the whole economy. The data consists of one cross-section of the Flemish economy surveyed in 2013 about their activities in the period spanning 2010-2012. We use the survey carried out in 2013 since it includes unique questions on IP litigation. The sample covers firms in the manufacturing as well as services sector.

As the subsequent empirical study focuses on IP litigation and innovation, we only retain the subsample of innovating companies. According to the international guidelines for collecting innovation data from the business sector as described by the OSLO manual, an innovation is defined as:

> *An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations. (OECD Publishing, 2005)*

We add to the survey data patent stock, patent quality and technology base fragmentation variables retrieved from PATSTAT. Additionally we also collected information on the firms cash position from the Belgian part of the ORBIS database, Belfirst.

Considering item non-response on the variables used in our specifications and outlier deletion, the final estimation sample counts 733 observations.

III.B. Dependent Variables – IP Litigation

Regarding IP litigation, we consider three binary outcome variables measuring different IP infringement litigation modes that companies potentially encountered in the surveyed period. PLAINTIFF indicates whether a company was a plaintiff in an IP infringement case, i.e. the company owned IPRs and accused at least one other firm of infringement. DEFENDANT indicates whether a company was a defendant in an IP infringement case. Whether a company was involved in settlement negotiations or arrangements outside the court of law with the purpose of avoiding IPR disputes is indicated by SETTLE. Note that the three litigation outcome variables are not mutually exclusive.

From the descriptive statistics in table I we see that the IP infringement litigation modes considered occur for a relatively small but still reasonable proportion of firms. About 6% of the firms go to court as a plaintiff whereas about 5% are being sued in court as a defendant. Settlement arrangements outside court happened for 7% of firms in the sample.

Additionally, we consider two binary outcome variables indicating the reaction of the defendant to the accusation. If a defendant doubts the validity of the supposedly infringed upon IP, they can file for nullification of the intellectual property rights. PLAINTIFF NULL indicates whether, in response to the initial accusation by the focal company, the defendant filed for

nullification of the IPR. This happens in 33% of the cases. Correspondingly, DEFENDANT NULL indicates whether the focal company filed for nullification if it was accused of IP infringement. This happens in 66% of all cases in our sample.[18] As our dependent variables are binary, we subsequently estimate Probit models.

III.C. Covariates of Interest – Market Value Measures of Innovation and Patent Portfolio Value Measures

The main interest of the analysis lies in relating the dependent (IP litigation) variables to market value proxies of innovation, and whether these have additional explanatory power on top of commonly used technological value proxies of the IP portfolio.

Regarding the market value of a company's innovation portfolio three components of turnover can be identified based on the survey: (a) sales from market novelties (i.e. products, goods or services, newly introduced to the market between 2010 and 2012), (b) sales from imitation and incremental innovation (i.e. products introduced in the period 2010-2012 that were new to the firm but not new to the market), (c) sales of unchanged products. The average turnover per employee originating from market novelties, NOVEL SALES, and new-to-firm innovations, IMITATION SALES, are € 23 688 and € 18 671 respectively. From the companies in the

[18] For the population one would suspect these percentages to be equal, i.e. it concerns a symmetrical setup where the nullification strategy of firms is once perceived as a defendant that files for nullification and once as a plaintiff that is confronted with nullification. Filing for nullification is in this setup always done by the party that does not own the IP. The fact that we find diverging percentages can be explained as a small sample issue since we only observe a fraction of the litigation suits in the full population. The fact that the percentages seem to add up to 100% is purely coincidence.

sample, 48% generated no sales from market novelties, whereas 52% generated no sales from new-to-firm innovations, i.e. imitation.

We construct three variables from the Patstat database which proxy the importance, quality, and composition of the patent portfolio: depreciated patent stock per employee (PATENT INTENSITY), patent quality (PATENT QUALITY), and fragmentation of prior art (FRAGMENTATION). In calculating these measures the patent application and citation data is truncated at 2010. Patent stock for firm *i* in year *t* was retrieved by applying the following formula:

$$\text{PATENSTOCK}_{it} = (1-\delta)\ \text{PS}_{it-1} + \text{patent applications}_{it}$$

where δ, the constant knowledge depreciation rate, is set to 15%. As the patent stock might be highly correlated with firm size, we use the variable PATENT INTENSITY in the regressions that further scales the patent stock per employee. The patent applications are aggregated on the family level to obtain unique inventions. To mitigate endogeneity concerns this variable enters our specification as measured in 2010, i.e. before the period in which litigation is measured. From the companies in our sample about 10% has a strictly positive patent stock in 2010.

PATENT QUALITY measure average quality of patents, i.e. the average number of forward citations to a patent within the company's patent portfolio, and also enters as measured in 2010. All forward citations from the PATSTAT extract up to 2010 are counted.

$$\text{PATENT QUALITY}_i = \frac{(\ \#\ \text{forward citations revieved by firm i within a 5-year citation window}\ )}{(\#\ patents\ filed\ by\ firm\ i)}$$

Ziedonis (2004) calculates a patent fragmentation index by:

$$\text{FRAGMENTATION}_\text{i} = 1 - \sum_{\text{j}=1}^{\text{J}} \left(\frac{\#\text{nbcites}_\text{ij}}{\#\text{nbcites}_\text{i}}\right)^2, \text{i} \neq \text{j}$$

where,

$nbcites_i$= total number of backward citations for the patent portfolio of company i

$nbcites_{ij}$= total number of backward citations that the patent portfolio of company i makes to patents of company j.

Our fragmentation index is calculated accordingly for all patents a firm has in its portfolio and might indeed influence litigation propensities as a more fragmented technology base makes infringement more likely (Heller & Eisenberg, 1998).

Since we look at litigation in relation to IP in general (in contrast to the literature on patent litigation in specific) we consider the importance of other IP next to patents in the firms' portfolios. We thus also use trademarks as an appropriation mechanism for innovation (Mendonça et al., 2004). Industrial designs, which are more frequently infringed upon (Weatherall et al., 2009), should also be considered from the broader IP perspective. Dummy variables indicating whether the firm used industrial designs (DESIGN) and trademarks (TRADEMARK) as means of improving their competitive position are also available from the survey.

III.D. Independent Variables – Controls

The necessity of R&D intensity as a control variable is apparent as: (a) intensive imitative R&D or (b) original own R&D efforts both increase the potential for infringement cases and thus trigger litigation (cf. Bessen & Meurer, 2006). We measure R&D INTENSITY as intramural R&D spending per employee in 2012.

Further general controls are firm size measured as number of employees (EMPLOYMENT) and age as years elapsed since foundation (AGE). Large and established firms might be more involved in IP litigation given the high cost of such trials (Bessen &

Meurer, 2006, Hall & Ziedonis, 2007). We further consider the firms volume of cash and cash equivalent available (CASH) since firms with deep pockets might hesitate less to engage in litigation as the trial cost may not be a significant expense for them. A control for whether a firm handles legal IP issues in a separate department, IPDEPT, is also available. Finally, considering the appropriability literature stressing the diverging effectiveness of patent in different technological areas (e.g. Teece, 1986), sector dummies are used to control for inter-sectorial differences.

III.E. Descriptive Statistics

Summary statistics can be found in table I. The average firm in our sample has about 115 employees and sells good and services of about € 300,000 per employee. Most sales are achieved with products that existed at least three year ago (i.e. before our sample period 2010). On average, firms achieve € 260,000 per employee from unchanged products. The remaining € 40,000 per employee are almost split evenly between market novelties and imitation where market novelties amount to € 23,688 and € 18,671.

Table II shows the correlation matrix. There is no evidence of severe multicollinearity among our variables. The highest correlations between two explanatory variables occur between DESIGN and TRADEMARK with a correlation coefficient of 0.44, and between FRAGMENTATION and PATENT INTENSITY with 0.49.

Table III summarizes the final sample's distribution over the sectors. Most innovative firms in the sample are in knowledge intensive services, i.e. telecommunications, software and engineering services (202 observations). This is followed manufacture of food products, beverages, textiles and leather.

III.F. Sample Splits

In table IV we further split up the descriptive statistics by the three main outcome variables (PLAINTIFF, DEFENDANT, and SETTLE).

Companies involved in any kind of litigation or settlement procedure score higher on all right-hand side variables, meaning they generate more turnover per employee from novelties and imitations, are larger and older, are more R&D and patent intensive, have higher quality patents, draw from a more fragmented technology base, and are more likely to use trademarks and industrial designs. PLAINTIFFS tend to generate a higher turnover per employee from market novelties than DEFENDANTS, whereas DEFENDANTS have a higher turnover per employee generated from imitation and incremental innovation. Companies involved in SETTLEMENTS generate, on average, turnovers from novelties and imitations that lie in between the corresponding values of PLAINTIFFS and DEFENDANTS.

Table I. Descriptive Statistics

Variable	Variable description	μ	σ	Min	Max
Main set of Dependent variables (N = 733)					
PLAINTIFF	Dummy = 1 if a company was plaintiff in an IP lawsuit	0.06	0.23	0	1
DEFENDANT	Dummy = 1 if a company was defendant in an IP lawsuit	0.05	0.21	0	1
SETTLE	Dummy = 1 if a company negotiated outside of court for a settlement on an IP dispute	0.07	0.26	0	1
2nd set of dependent variables only observed if plaintiff or defendant take value 1, respectively					
PLAINTIFF NULL	Dummy = 1 if the defendant followed up with a request for nullification of the IP when the variable plaintiff above is equal 1.	0.33	0.48	0	1
DEFENDANT NULL	Dummy = 1 if the variable defendant above was equal to one and they initiated a nullification suit against the respective plaintiff.	0.66	0.48	0	1
Covariates (N = 733)					
SALES PRODUCTIVTY	(Turnover in € 1 000 000) / #employees	0.3	0.33	0	2.95
NOVEL SALES	(Turnover with market novelties in € 1 000 000) / #employees	0.02	0.05	0	0.33
IMITATION	(Turnover with imitation or incremental innovation in € 1 000 000) / #employees	0.02	0.04	0	0.24
UNCHANGED	(Turnover with unchanged products in € 1 000 000) / #employees	0.26	0.32	0	2.95
EMPLOYMENT	# employees	115.05	298.17	3	3828
AGE	2013- year of foundation	27.57	18.03	3	145
R&D INTENSITY	Internal R&D expenditures / # employees	10.67	23.98	0	230.28
PATENT INTENSITY	Depreciated patent stock per employee	0.01	0.04	0	0.45
PATENT QUALILTY	Average # of forward citations per patent	0.28	1.6	0	24
FRAGMENTATION	Measure of patent fragmentation (Ziedonis, 2004)	0.19	0.37	0	1
CASH AVAILABLE	Cash and cash equivalent (Bureau van Dijck – Belfirst) in € 1 000 000 000	0.01	0.03	0	0.63
IP DEPARTMENT	Indicates whether IP tasks are handled by a separate entity	0.17	0.38	0	1
DESIGN (DUMMY)	Dummy = 1 if the company used industrial designs for improving their competitive position	0.18	0.39	0	1
TRADEMARK (DUMMY)	Dummy = 1 if the company used trademarks for improving their competitive position	0.34	0.47	0	1

Table II. Pairwise correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.PLAINTIFF (DUMMY)	1														
2. DEFENDANT (DUMMY)	0.34	1													
3. SETTLE (DUMMY)	0.65	0.56	1												
4. NOVEL SALES	0.18	0.13	0.13	1											
5. IMITATION	0.08	0.13	0.12	0.19	1										
6. UNCHANGED	0.02	0.17	0.03	-0.02	0.04	1									
7. EMPLOYMENT	0.28	0.19	0.25	0.04	0.01	0.18	1								
8. AGE	0.11	0.03	0.09	-0.04	-0.06	0.17	0.26	1							
9. R&D INTENSITY	0.23	0.29	0.27	0.32	0.1	-0.08	0.13	-0.12	1						
10. PATENT INTENSITY	0.24	0.19	0.21	0.21	0.08	0.08	0.06	-0.06	0.31	1					
11. PATENT QUALILTY	-0.01	-0.02	0.01	0.13	-0.03	0.04	0.02	-0.01	0.07	0.02	1				
12. FRAGMENTATION	0.25	0.22	0.25	0.13	0.04	0.1	0.28	0.09	0.24	0.49	0.29	1			
13. CASH AVAILABLE	0.22	0.16	0.21	0.01	0.01	0.08	0.44	0.04	0.09	0.07	0	0.15	1		
14. IP DEPARTMENT	0.25	0.2	0.3	0.14	0.02	0.11	0.26	0.09	0.19	0.15	0.08	0.3	0.18	1	
15. DESIGN (DUMMY)	0.29	0.24	0.24	0.16	0.05	0.03	0.15	0.05	0.18	0.15	-0.01	0.27	0.01	0.21	1
16. TRADEMARK (DUMMY)	0.21	0.14	0.21	0.14	0.11	0.01	0.12	0.08	0.16	0.1	0.04	0.2	0.08	0.25	0.44

Table III. Distribution over Sectors

Sectors	Sector description	Observations	R. Freq
Sector1	food, beverage, tobacco, textile, clothing and leather industries	94	0.13
Sector2	Textile, clothing and leather industry	34	0.05
Sector3	Manufacture of cokes, chemicals, pharmaceuticals, rubber and plastic	83	0.11
Sector4	Manufacture of non-ferro minerals, metals and metal products (no machinery and equipment)	73	0.10
Sector5	Manufacture of electrical equipment, IT-products, electronic and optical products	51	0.07
Sector6	Manufacture of machinery, equipment, tools and transport	55	0.08
Sector7	Wholesale	84	0.11
Sector8	Telecomunication, software design and programming, computer-consultancy, information services, architects and engineering, R&D	202	0.27
Sector9	Remaining sub-sectors	57	0.08

Table IV. Descriptive Statistics Split According to Outcome Variables

Variable	μ	σ	Min	Max	μ	σ	Min	Max	μ	σ	Min	Max
	plaintiff subsample (41 observations)				**defendant subsample (35 observations)**				**settlement subsample (52 observations)**			
PLAINTIFF	1	0	1	1	0.4	0.5	0	1	0.6	0.5	0	1
DEFENDANT	0.34	0.48	0	1	1	0	1	1	0.48	0.5	0	1
SETTLE	0.76	0.43	0	1	0.71	0.46	0	1	1	0	1	1
NOVEL SALES	0.06	0.08	0	0.33	0.05	0.06	0	0.27	0.05	0.07	0	0.27
IMITATION	0.03	0.06	0	0.24	0.04	0.06	0	0.21	0.03	0.06	0	0.24
UNCHANGED	0.29	0.26	0	1.27	0.5	0.62	0	2.39	0.29	0.31	0	1.88
EMPLOYMENT	456.66	763.52	7	3828	367.91	794.27	4	3828	385.73	687.84	5	3828
AGE	35.8	26.09	7	117	30.11	22.55	3	88	33.73	24.41	3	117
R&D INTENSITY	33.38	58.07	0	230.28	41.27	62.93	0	230.28	33.95	54.37	0	230.28
PATENT INTENSITY	0.05	0.09	0	0.45	0.04	0.09	0	0.45	0.04	0.08	0	0.45
PATENT QUALILTY	14.37	29.24	0	151	14.71	35.43	0	151	16.81	33.64	0	151
FRAGMENTATION	0.57	0.47	0	1	0.56	0.47	0	1	0.53	0.48	0	1
CASH AVAILABLE	0.04	0.11	0	0.63	0.03	0.11	0	0.63	0.03	0.1	0	0.63
IP DEPARTMENT	0.56	0.5	0	1	0.51	0.51	0	1	0.58	0.5	0	1
DESIGN (dummy)	0.63	0.49	0	1	0.6	0.5	0	1	0.52	0.5	0	1
TRADEMARK (dummy)	0.76	0.43	0	1	0.63	0.49	0	1	0.71	0.46	0	1
	non-plaintiff subsample (692 observations)				**non-defendant subsample (698 observations)**				**non-settlement subsample (681 observations)**			
PLAINTIFF	0	0	0	0	0.04	0.19	0	1	0.01	0.12	0	1
DEFENDANT	0.03	0.17	0	1	0	0	0	0	0.01	0.12	0	1
SETTLE	0.03	0.17	0	1	0.04	0.19	0	1	0	0	0	0
NOVEL SALES	0.02	0.04	0	0.32	0.02	0.04	0	0.33	0.02	0.04	0	0.33
IMITATION	0.02	0.03	0	0.23	0.02	0.03	0	0.24	0.02	0.03	0	0.23
UNCHANGED	0.26	0.33	0	2.95	0.24	0.3	0	2.95	0.25	0.32	0	2.95
EMPLOYMENT	94.8	230.44	3	3520	102.37	243.36	3	3520	94.38	232.79	3	3520
AGE	27.09	17.35	3	145	27.45	17.79	3	145	27.1	17.39	3	145
R&D INTENSITY	9.33	19.54	0	186.07	9.14	19.02	0	186.07	8.89	18.79	0	186.07
PATENT INTENSITY	0.01	0.03	0	0.4	0.01	0.04	0	0.4	0.01	0.03	0	0.4
PATENT QUALILTY	2.63	16.28	0	274	2.71	15.86	0	274	2.25	15.09	0	274
FRAGMENTATION	0.17	0.35	0	1	0.17	0.36	0	1	0.16	0.35	0	0.99
CASH AVAILABLE	0.00	0.02	0	0.37	0.00	0.02	0	0.37	0.00	0.02	0	0.37
IP DEPARTMENT	0.15	0.35	0	1	0.15	0.36	0	1	0.14	0.35	0	1
Design (dummy)	0.15	0.36	0	1	0.16	0.37	0	1	0.16	0.36	0	1
TRADEMARK (dummy)	0.32	0.47	0	1	0.33	0.47	0	1	0.31	0.46	0	1

III.G. Robustness to Sample Selection due to Non-Response and Outlier Deletion

Given that due to outlier deletion and item non-response the size of the original sample of the survey shrank , we checked whether our results are robust when sampling weights are taken into account. All results below remain valid when running these weighted regressions (Results are not reported).

IV. RESULTS AND DISCUSSION

IV.A. Initial litigation propensities (RQ1) – Main results

In table V and VI we estimate Probit models. For all models, we employ clustered standard errors at the NACE 3-digit industry level (which is more detailed than the included sector dummies) in order to allow for error term correlation across observations within the same industry. It could happen that the models explain IP disputes better (or worse) in certain industries where IPR is very relevant for firms' main business strategies when compared to others where IP plays a smaller role. Clustered standard errors would account for the resulting error term correlation patterns across observations. Initially, in table V, we regress the outcome variables on total sales per employee and the controls. In table VI, we split the sales per employee into its three relevant components, sales with innovations, sales with imitations and sales with unchanged products.

The first specifications (1)-(3) only include the general firm level control variables next to our variables of interest in the regressions. In the extended specifications (4)-(6) control variables for the patent intensity (= patent stock per employee), patent quality (forward citations per patent), and the fragmentation index are added. In the columns (7)-(9) the design and trademark dummies are added.

In table V, we find that total sales per employee do only explain the defendant dummy significantly, but not the plaintiff nor the settlement dummy. When the total sales are split into

the components of NOVEL SALES, IMITATION, and UNCHANGED in Table VI, interesting differences are found. NOVEL SALES are positively associated with the likelihood to become a plaintiff. We interpret this finding as evidence that firms obtaining higher returns from their market novelties, i.e. their own, internally developed innovations are more likely to enforce their IPRs than firms that have only less successful innovations. This finding is consistent with the view that the "value at stake" determines litigation events. Accordingly, we also find that the higher the sales with imitation, the more likely firms are to become defendant in an IP dispute. The "value at stake" argumentation also holds in this case. An IP owner may be more likely to enforce IP, the more returns others achieve with related or imitated products. In the case of settlement, we find that sales with imitation are positively associated with settlement, but market novelty sales are insignificant. All these findings are significant at the 5% level and remain robust across all specifications. The unchanged products turn out to be positively significant in the DEFENDANT model only. This might indicate simply that very successful firms, e.g. the market leaders, are more likely to be targets of litigation suits.

Table V. Litigation Propensities - Single Equation Probit Estimations – Sales per Employee not Split

b/(se)	(1) Plaintiff	(2) Defendant	(3) Settle	(4) Plaintiff	(5) Defendant	(6) Settle	(7) Plaintiff	(8) Defendant	(9) Settle
SALES/EMPLOYM.	0.102	0.748***	0.060	-0.301	0.698***	-0.221	-0.243	0.686***	-0.183
	(0.263)	(0.157)	(0.208)	(0.391)	(0.157)	(0.254)	(0.365)	(0.164)	(0.244)
EMPLOYMENT	0.001***	0.000*	0.001***	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.007	-0.002	0.005	0.008	-0.003	0.003	0.007	-0.004	0.003
	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
R&D INTENISTY	0.016***	0.014***	0.016***	0.012***	0.011***	0.011***			
	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)			
PATENT INTENSITY				4.680**	0.949	2.780	5.232***	2.180*	3.876**
				(2.385)	(1.125)	(1.891)	(1.796)	(1.278)	(1.632)
PATENT QUALITY				0.026	-0.079	0.054	0.033	-0.040	0.058*
				(0.037)	(0.062)	(0.035)	(0.029)	(0.055)	(0.035)
FRAGMENTATION				0.000	0.480*	-0.042	0.088	0.502*	0.031
				(0.262)	(0.265)	(0.257)	(0.242)	(0.263)	(0.248)
CASH AVAILABLE				4.066***	2.352*	3.462***	3.647***	2.131	3.335***
				(1.287)	(1.398)	(1.244)	(1.281)	(1.376)	(1.257)
IP DEPARTMENT				0.646***	0.418*	0.790***	0.655***	0.470*	0.804***
				(0.240)	(0.252)	(0.201)	(0.230)	(0.242)	(0.189)
DESIGN				0.879***	0.708***	0.555**	0.858***	0.758***	0.568**
				(0.237)	(0.238)	(0.248)	(0.246)	(0.230)	(0.238)
TRADEMARK				0.488*	0.070	0.475**	0.528**	0.149	0.513**
				(0.258)	(0.224)	(0.233)	(0.264)	(0.229)	(0.233)
Intercept	-2.352***	-2.041***	-1.795***	-2.976***	-2.252***	-2.172***	-2.982***	-2.299***	-2.184***
	(0.365)	(0.271)	(0.210)	(0.434)	(0.289)	(0.237)	(0.434)	(0.295)	(0.241)
Sector- dummies	Incl.***	Incl.	Incl.***	Incl.***	Incl.	Incl.***	Incl.***	Incl.	Incl.
Pseudo R2	0.218	0.205	0.175	0.326	0.261	0.275	0.414	0.309	0.325
#obs	733	733	733	733	733	733	733	733	733

(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.; standard errors clustered at the NACE 3-digit level; all artrho coefficients significant at the 1 pct. Level)

Table VI. Litigation Propensities - Single Equation Probit Estimations – Sales per Employee Split by Sales Categories

b/(se)	(1) Plaintiff	(2) Defendant	(3) Settle	(4) Plaintiff	(5) Defendant	(6) Settle	(7) Plaintiff	(8) Defendant	(9) Settle
NOVEL SALES	3.755**	1.098	1.161	3.345*	1.013	-0.553	4.545**	2.733	1.304
	(1.666)	(1.393)	(1.651)	(1.868)	(1.580)	(1.913)	(1.903)	(1.865)	(2.160)
IMITATION	3.287	4.158**	4.230**	3.139	4.317**	4.901**	3.338	4.325**	4.972**
	(2.059)	(1.659)	(1.745)	(2.772)	(1.921)	(2.028)	(2.613)	(1.975)	(1.967)
UNCHANGED	-0.16	0.693***	-0.079	-0.654	0.640***	-0.380	-0.694*	0.590***	-0.444
	(0.271)	(0.176)	(0.266)	(0.410)	(0.184)	(0.286)	(0.398)	(0.202)	(0.299)
EMPLOYMENT	0.001***	0.000*	0.001***	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.008*	-0.001	0.006	0.009**	-0.002	0.005	0.009**	-0.003	0.004
	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)
R&D INTENISTY	0.013***	0.014***	0.015***	0.010***	0.011***	0.011***			
	(0.003)	(0.003)	(0.001)	(0.004)	(0.003)	(0.002)			
PATENT INTENSITY				3.996*	0.592	2.866	4.261**	1.277	3.387**
				(2.279)	(1.234)	(2.066)	(1.795)	(1.369)	(1.605)
PATENT QUALITY				0.015	-0.081	0.057	0.016	-0.051	0.055
				(0.038)	(0.062)	(0.036)	(0.031)	(0.054)	(0.036)
FRAGMENTATION				0.157	0.514*	-0.036	0.259	0.575**	0.090
				(0.281)	(0.275)	(0.273)	(0.261)	(0.268)	(0.260)
CASH AVAILABLE				4.467***	2.448*	3.615***	4.231***	2.332*	3.599***
				(1.327)	(1.384)	(1.322)	(1.315)	(1.365)	(1.349)
IP DEPARTMENT				0.655***	0.429*	0.810***	0.658***	0.474*	0.825***
				(0.254)	(0.253)	(0.211)	(0.253)	(0.245)	(0.201)
DESIGN				0.905***	0.710***	0.579**	0.891***	0.751***	0.584**
				(0.237)	(0.234)	(0.249)	(0.245)	(0.227)	(0.242)
TRADEMARK				0.433*	0.030	0.450*	0.446*	0.075	0.452**
				(0.261)	(0.212)	(0.234)	(0.262)	(0.211)	(0.229)
Intercept	-2.448***	-2.168***	-1.921***	-3.070***	-2.372***	-2.312***	-3.082***	-2.432***	-2.309***
	(0.399)	(0.274)	(0.211)	(0.477)	(0.290)	(0.237)	(0.481)	(0.298)	(0.242)
Sector- dummies	Incl.***	Incl.	Incl.***	Incl.***	Incl.	Incl.***	Incl.***	Incl.	Incl.*
Pseudo R2	0.244	0.216	0.191	0.427	0.325	0.345	0.409	0.290	0.320
#obs	733	733	733	733	733	733	733	733	733

(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.; standard errors clustered at the NACE 3-digit level; all artrho coefficients significant at the 1 pct. Level)

In order to interpret the economic magnitude of the estimated effects for the main variables of interest, we calculate the change in predicted probabilities when the right hand side variable changes from its mean value to the mean plus one standard deviation. First, the predicted probability of becoming a plaintiff at the mean value of all regressors is 0.91%. When increasing the value of NOVEL SALES with one standard deviation, this predicted probability becomes 1.55%, i.e. the economic effect is sizable. While litigation, on average, is certainly a rare event still, the increase of a standard deviation in NOVEL SALES increases the likelihood to sue for infringement by about 70% (= 1.55/0.91 ¬ 1) Second, the predicted probability of becoming a defendant at the mean value of all regressors is 2.01%. When increasing the value of IMITATION SALES with one standard deviation, this predicted probability becomes 2.95%, i.e. a 46% increase. Finally, the predicted probability of being involved in out of court settlements at the mean value of all regressors is 2.3%. When increasing the value of IMITATION SALES with one standard deviation, this predicted probability becomes 3.6%, i.e. a 50% increase.

Regarding the other control variables, the patent intensity is positively and significantly associated with the probability to become a plaintiff in Table V an VI. This is in line with a large body of previous literature and is also the expected result; a firm owning more IP will also be more likely to enforce (parts of) it. Interestingly, this significant relationship disappears once the market positions of firms enter the models more flexibly, i.e. the sales are split into novel product sales, imitation and unchanged products. We interpret this as indication that market success is driving litigation and not just IP ownership (that might not lead to significant returns in the market). A result that is statistically insignificant is the patent quality, though. If one would interpret patent quality measured by forward citations as having “solid and relevant inventions” it would make sense that the estimated coefficient is negative. Often, however,

scholars associate forward citations with economic value and then this result would stand in contrast with the "value at stake" interpretation. We believe that we already control for many other factors that determine "value at stake" and that indeed the negative influence of patent quality in the defendant regression might show that the corresponding firm possess own, relevant and high quality IP and is therefore simply less likely to infringe others' IP and is consequently less challenged. The fragmentation variable correlates positively and significantly with PLAINTIFF and DEFENDANT in Table VI in models (4) and (5). When DESIGN and TRADEMARK are added to the models, this relationship disappears, though. The DESIGN coefficient itself is positive and significant in all three equations whereas the TRADEMARK is only positively significant in the regression on SETTLE.

With regard to the remaining controls, R&D intensity is positive and significant throughout at the 5% level. This finding is consistent with prior literature (e.g. Bessen and Meurer, 2006) as R&D may serve as proxy for future values at stake. Very R&D intensive firms may critically depend on innovations and their future market success and therefore engage in IP disputes, and they of course might simply have more to dispute about as they conduct high levels of R&D. Firm age is positive and weakly significant in the PLAINTIFF regressions; otherwise insignificant. The CASH variable is positive and significant in most models. This suggests, on one hand, that firms with deep pockets hesitate less to get involved in IP disputes. On the other hand, this result is also consistent with the "value at stake" interpretation if cash holdings are seen as retained earnings that may partly stem from returns of new product sales (either market novelties or imitation). Firms earning more have more to lose (or "steal" more from others in case of the defendant equation), and therefore are more likely to be in IP disputes. The variable IP department is positive and significant in all regressions. This is not surprising as firms with a dedicated IP know-how will probably find more opportunities regarding legal

dimension of IPRs. The sector controls are jointly significant in the PLAINTIFF and SETTLE regressions but not in the DEFENDANT regression.

IV.B. Initial litigation propensities (RQ1) – Robustness checks

We also estimated the same specifications using multivariate Probit models, i.e. we account for possible error term correlations across the equations. In comparison to the single equation Probits, one could gain efficiency when error term correlation is taken into account. The results are robust but do not improve significantly (Table VII) .

Furthermore, we also tested rare event logit models, as the positive outcomes of our dependent variable are not very frequent. The rare event logit models following King and Zeng (2001) may also lead to more efficient estimates in case of rare positive outcomes. Again our results remain robust but do not really improve in any economically interesting way either (Table VIII).

We also conducted several sample splits. Our results on IMITATION SALES hold for regressions considering: a) only smaller firms, i.e. less than 50 employees, b) manufacturing firms, and c) younger firms, i.e. founded after 1988. The results on NOVELTY SALES are less stable and become less significant when these sample splits are applied. We therefore conclude that even for small and young firms IP disputes are either a relevant threat or also mechanism to defend IP. Even though there are some very prominent global examples of IP disputes in services (e.g. Google etc.), IP disputes seem to be more driven by the manufacturing sector still, and not by services. This is not too surprising when using European data though, as software is not patentable in Europe.

Table VII. Litigation propensities – Simultaneous Equations Probit Estimations

b/(se)	(1) Plaintiff	(2) Defendant	(3) Settle	(4) Plaintiff	(5) Defendant	(6) Settle	(7) Plaintiff	(8) Defendant	(9) Settle
NOVEL SALES	3.961***	1.084	1.159	3.290*	0.958	-0.718	4.283**	2.368	0.598
	(1.516)	(1.422)	(1.380)	(1.778)	(1.701)	(1.543)	(1.827)	(2.049)	(1.899)
IMITATION	2.567	3.835**	3.824**	2.552	3.606**	3.729*	2.671	3.632*	3.924**
	(2.121)	(1.877)	(1.827)	(2.808)	(1.839)	(1.983)	(2.695)	(1.979)	(1.945)
UNCHANGED	-0.101	0.766***	0.097	-0.611*	0.698***	-0.124	-0.646*	0.646***	-0.149
	(0.233)	(0.171)	(0.254)	(0.364)	(0.190)	(0.256)	(0.363)	(0.208)	(0.293)
EMPLOYMENT	0.001***	0.000*	0.001***	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.006	-0.001	0.004	0.007	-0.004	0.003	0.007	-0.005	0.002
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
R&D INTENISTY	0.013***	0.013***	0.014***	0.008**	0.010***	0.009***			
	(0.003)	(0.003)	(0.001)	(0.003)	(0.002)	(0.003)			
PATENT INTENSITY				4.108**	0.785	2.650*	4.583***	1.647	3.193**
				(1.903)	(1.382)	(1.465)	(1.737)	(1.626)	(1.529)
PATENT QUALITY				0.018	-0.101*	0.050	0.023	-0.076	0.053
				(0.044)	(0.060)	(0.042)	(0.040)	(0.058)	(0.040)
FRAGMEN-TATION				0.109	0.519*	-0.012	0.156	0.556**	0.059
				(0.281)	(0.268)	(0.238)	(0.291)	(0.260)	(0.244)
CASH AVAILABLE				4.393***	2.123	3.237**	4.351***	1.983	3.083**
				(1.367)	(1.371)	(1.354)	(1.314)	(1.346)	(1.423)
IP DEPARTMENT				0.565**	0.394	0.676***	0.585**	0.444*	0.702***
				(0.228)	(0.248)	(0.198)	(0.237)	(0.242)	(0.215)
DESIGN				0.841***	0.564**	0.470*	0.861***	0.597***	0.488**
				(0.226)	(0.234)	(0.240)	(0.225)	(0.229)	(0.231)
TRADEMARK				0.556**	0.179	0.521**	0.559**	0.216	0.508**
				(0.234)	(0.195)	(0.212)	(0.230)	(0.199)	(0.211)
Intercept	-2.389***	-2.180***	-1.939***	-3.021***	-2.306***	-2.268***	-3.009***	-2.332***	-2.261***
	(0.345)	(0.272)	(0.195)	(0.457)	(0.288)	(0.223)	(0.469)	(0.301)	(0.245)
Sector- dummies	Incl.***	Incl.	Incl.**	Incl.***	Incl.	Incl.**	Incl.***	Incl.	Incl.
#obs	733	733	733	733	733	733	733	733	733

(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.; standard errors clustered at the NACE 3-digit level; all artrho coefficients significant at the 1 pct. Level)

Table VIII. Litigation propensities – Single Equation Rare Event Logit Estimations

b/(se)	(1) Plaintiff	(2) Defendant	(3) Settle	(4) Plaintiff	(5) Defendant	(6) Settle	(7) Plaintiff	(8) Defendant	(9) Settle
NOVEL SALES	7.800**	2.293	3.115	6.269*	1.812	-0.298	7.946**	4.928	2.901
	(3.036)	(2.687)	(3.240)	(3.681)	(2.871)	(3.696)	(3.520)	(3.672)	(4.144)
IMITATION	6.005	8.872***	7.989**	5.356	8.374**	9.191**	5.571	8.167**	8.935**
	(3.731)	(3.348)	(3.181)	(6.179)	(3.847)	(3.837)	(5.646)	(3.990)	(3.721)
UNCHANGED	-0.355	1.325***	-0.135	-0.967	1.125***	-0.526	-1.150	1.007***	-0.684
	(0.599)	(0.340)	(0.572)	(0.794)	(0.355)	(0.572)	(0.769)	(0.388)	(0.614)
EMPLOYMENT	0.001***	0.001	0.001***	0.001	0.000	0.000	0.001	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
AGE	0.017**	-0.001	0.014*	0.014	-0.005	0.009	0.014	-0.004	0.007
	(0.009)	(0.010)	(0.008)	(0.010)	(0.010)	(0.008)	(0.009)	(0.010)	(0.009)
R&D INTENISTY	0.021***	0.024***	0.024***	0.015**	0.019***	0.019***			
	(0.006)	(0.004)	(0.003)	(0.007)	(0.005)	(0.003)			
PATENT INTENSITY				6.051	1.554	5.371	6.602*	1.809	5.702*
				(4.659)	(2.577)	(4.289)	(3.593)	(2.514)	(2.987)
PATENT QUALITY				0.047	-0.125	0.106*	0.039	-0.082	0.086
				(0.076)	(0.126)	(0.062)	(0.061)	(0.125)	(0.064)
FRAGMEN-TATION				0.298	0.948*	-0.043	0.496	1.082**	0.272
				(0.617)	(0.569)	(0.557)	(0.567)	(0.548)	(0.512)
CASH AVAILABLE				6.089***	3.135	4.885**	5.628***	2.796	4.756*
				(2.104)	(2.339)	(2.268)	(2.161)	(2.276)	(2.475)
IP DEPARTMENT				1.091**	0.717	1.434***	1.120**	0.830	1.460***
				(0.494)	(0.519)	(0.408)	(0.529)	(0.514)	(0.413)
DESIGN				1.461***	1.217***	0.998**	1.451***	1.310***	1.005**
				(0.509)	(0.465)	(0.484)	(0.540)	(0.471)	(0.483)
TRADEMARK				0.777	0.190	0.798*	0.811	0.254	0.780*
				(0.574)	(0.442)	(0.476)	(0.598)	(0.453)	(0.472)
Intercept	-4.254***	-3.934***	-3.374***	-4.974***	-4.107***	-3.926***	-4.993***	-4.291***	-3.872***
	(0.871)	(0.625)	(0.437)	(1.014)	(0.610)	(0.473)	(1.015)	(0.635)	(0.489)
Sector- dummies	Incl.***	Incl.	Incl.	Incl.***	Incl.	Incl.***	Incl.***	Incl.	Incl.
#obs	733	733	733	733	733	733	733	733	733

(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.; standard errors clustered at the NACE 3-digit level; all artrho coefficients significant at the 1 pct. Level)

IV.C. Requests for Nullification (RQ2) – Main Results

In table IX we report regression results explaining requests for nullification of the underlying IP conditional on an IP dispute. There we estimate single equation Probit models using all covariates except the industry dummies as we only have 35 and 39 observations, respectively. We checked the robustness of these results by estimating Full Information Maximum Likelihood (FIML) Heckman selection models for two binary variables (see e.g. Wooldridge, 2002), i.e. conditional on a litigation court suit, the plaintiff or defendant respectively may file a nullification suit against the other involved party (see Table X). This has the advantage that we can use all 731 and 733 observations, respectively. However, when fitting the Heckman model, it turned out that we have to limit the number of covariates to achieve convergence in this more complex model. We only use the sales variables, the patent portfolio related variables and the age, employment and R&D intensity variables. The fragmentation index is used as exclusion restriction in the regression, i.e. this is included in the first stage on litigation suits (as also done in Tables V and VI), but excluded from the subsequent nullification regression.

If companies get sued, they ask nullification more frequently if the stakes they have with regard to sales from imitations are high. The effect is always significant at the 5% level and is indicative of imitators trying to protect their market stakes (supports H4).

Table IX. Subsequent Nullification Requests – Probit Estimations

b/(se)	(1) PlaintiffNull	(2) DefendantNull	(3) PlaintiffNull	(4) DefendantNull	(5) PlaintiffNull	(6) DefendantNull
NOVEL SALES	-1.290	-5.186	-1.287	-3.285	-1.476	-5.113
	(3.194)	(6.961)	(4.116)	(10.218)	(4.029)	(5.754)
IMITATION	6.628	9.202**	7.059	28.307**	7.487	26.460***
	(4.058)	(3.930)	(5.305)	(12.577)	(5.160)	(10.142)
UNCHANGED	-0.254	-0.559	-0.914	-1.713**	-1.136	-1.616**
	(1.144)	(0.460)	(1.600)	(0.829)	(1.559)	(0.727)
EMPLOYMENT	-0.000	0.002	0.000	0.004	0.001	0.004
	(0.000)	(0.002)	(0.001)	(0.003)	(0.000)	(0.003)
AGE	0.020**	0.010	0.042***	-0.004	0.040***	-0.001
	(0.010)	(0.018)	(0.014)	(0.024)	(0.014)	(0.021)
R&D INTENISTY	0.002	0.010	0.006	-0.004		
	(0.004)	(0.008)	(0.008)	(0.016)		
PATENT INTENSITY			9.841*	3.156	11.475***	2.798
			(5.288)	(10.162)	(3.921)	(9.731)
PATENT QUALITY			-0.419***	1.106	-0.393***	1.028*
			(0.143)	(0.714)	(0.151)	(0.621)
FRAGMENTATION			-0.336	-2.718*	-0.522	-2.476*
			(1.039)	(1.393)	(0.946)	(1.299)
CASH AVAILABLE			0.511	128.059**	0.848	119.941**
			(3.196)	(54.801)	(3.249)	(48.083)
IP DEPARTMENT			0.725	2.125*	0.762	1.929*
			(0.494)	(1.103)	(0.514)	(1.004)
DESIGN			0.709	-0.559	0.743	-0.649
			(0.728)	(0.873)	(0.717)	(0.716)
TRADEMARK			-1.115	-1.388	-1.156	-1.295
			(0.916)	(0.963)	(0.914)	(0.950)
Intercept	-1.354**	-0.368	-2.080**	0.141	-1.945**	0.105
	(0.539)	(0.560)	(0.849)	(0.730)	(0.814)	(0.769)
#obs	39	35	39	35	39	35

(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.; standard errors clustered at the NACE 3-digit level)

Table X. Subsequent Nullification Requests – Probit Models with Heckman Selection (FIML estimations)

b/(se)	(1) PlaintiffNull	(2) Plaintiff	(3) DefendantNull	(4) Defendant
NOVEL SALES	-3.485	2.708*	-5.794	1.177
	(3.644)	(1.416)	(6.757)	(1.366)
IMITATION	7.495	2.980	11.387***	4.247**
	(5.639)	(1.942)	(3.833)	(1.694)
UNCHANGED	-0.366	-0.347	-0.106	0.647***
	(1.247)	(0.295)	(0.532)	(0.151)
EMPLOYMENT	0.000	0.001***	0.001**	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
AGE	0.032***	0.009**	0.015	-0.000
	(0.012)	(0.004)	(0.015)	(0.005)
R&D INTENISTY	0.005	0.005**	0.013*	0.011***
	(0.006)	(0.002)	(0.007)	(0.002)
PATENT INTENSITY	6.797*	3.227**	0.252	0.303
	(3.792)	(1.497)	(7.520)	(1.135)
PATENT QUALITY	-0.289***	-0.048	0.271	-0.120*
	(0.095)	(0.039)	(0.261)	(0.061)
FRAGMENTATION		0.670**		0.885***
		(0.266)		(0.274)
Constant	-1.660	-2.392***	-2.379**	-2.454***
	(2.021)	(0.198)	(1.133)	(0.158)
#obs	731		733	
Censored	39		35	
Uncensored	692		698	
rho	Insignificant		Insignificant	

(Notes: Significance levels: *** 1 pct. or less; ** less than 5 pct. , * less than 10 pct.; standard errors clustered at the NACE 3-digit level; We use the measure of fragmentation as an exclusion restriction as it reasonably influences the initial litigation propensities, i.e. higher fragmentation means more potential counter parties, but not the propensity to request nullification, i.e. once confronted with a lawsuit the litigating parties do not let their decision to request nullification depend on how fragmented their technology base is.)

V. CONCLUSION

This paper presents new empirical evidence on the determinants of IP litigation at the firm level based on a sample of firms covered by the Flemish part of the 2013 wave of the Community Innovation Survey. Our study has several features that makes it different from the bulk of litigation studies: we conduct the analysis at the firm level, which has only been done in a few other papers. The firm level analysis allows to control for other factors beyond technological characteristics and other indicators derived from patent data. Our main novelty is the inclusion of the market position of firms regarding sales obtained with innovations, i.e. market novelties or imitation. We also consider retaliation actions through IP nullification suits as response to initial litigation actions. Furthermore, we also account for other IP than patents, namely registered industrial designs and trademarks, that might also lead to IP disputes. Finally, we also consider out-of-court settlements which have been largely ignored by prior literature. Other scholar only considered settlement within court trials. Our data show that out of court settlement occurs basically as frequently as formal litigation.

Market based measures of innovation and imitation seem to be important variables when analyzing litigation propensities. Our results are in line with theoretical models predicting a positive relation between value at stake and litigation propensity (see, among others, Bebchuk, 1984; Hirshleifer, 1991). Next to commonly used citation-based proxies for technological value of innovation, we find that our newly introduced market-based indicators on the value of innovations and imitations matter in explaining firm-level litigation and settlement propensities. We find that firms with a high turnover from innovative goods and services are more likely to sue over infringement of their IP, when controlling for technological importance and quality of the IP portfolio. Contrastingly, firms with a high turnover generated from imitations and

incremental innovations are sued more often over IP infringement. Facing fragmented IP in their technological space of activity adds to the likelihood of these firms being sued.

Also, the settling propensity of firms is positively influenced by sales from imitations while controlling for importance and quality of the IP portfolio. Infringers, however, seem also to settle more often when their market stakes involved are high, thereby avoiding costly litigation and uncertain court outcomes.

The nullification suits as response to a court trial are in line with the "value at stake" mechanism. Firms that are generating higher sales with imitations are more likely to respond with a nullification suit against the IP of the plaintiff than firms with less imitation.

Other IP such as trademarks and registered industrial designs have a significant explanatory power in the regressions on IP disputes, suggesting that these IPRs are also important to firms and are being enforced actively.

While we argue to have good measures of firms' market positions regarding their innovations and have a number of other interesting features in our empirical models, our study is of course not without limitations. The main limitation of this research remains possible endogeneity stemming from potential simultaneity between the outcome variables of IP disputes and the market-based measures of innovation and imitation. Addressing this concern appropriately in terms of the econometric approach seems almost impossible though. It would require identifying variables that independently affect the market positions but not the litigation propensity and, at the same time, do not depend on litigation. Commonly used variables that are constructed from information on product market rivals are conceptually ruled out in this case as these might also be involved in the court cases. Governmental regulation in sectors that exogenously affect sales of innovative products might be a solution, and a venue for future

research. However, such information is not easy to collect for a sample of firms stemming from a large number of sectors of the economy. It might require detailed data of a few innovative sectors where detailed institutional knowledge about regulation can be exploited for identification.

General Conclusion

This thesis set-out to empirically study how firms (inter-)act in order to appropriate the returns to their investments in R&D and innovation. I studied three pathways by which companies can shape the degree of appropriation of their R&D and innovation investments: preempting competition by building-up a lead time advantage *(chapter 1)*, taking out patents (*chapter 2)* and litigating (*chapter 3).*

In order to address these questions, I applied a modern empirical lens to the contemporary Belgian economy. Belgium, a relatively small, export oriented and innovative economy, might well be hit hard by the potential adverse effects of bad 'appropriation conditions' and constitutes a nice setting to investigate how 'appropriability conditions' and 'technological opportunities' crucially influence R&D and innovation incentives.

Chapter I investigated whether time-to-market considerations could be an alternative to patents for firms to better appropriate the returns of their R&D investments. Being able to out-innovate competitors in terms of time-to-market might put firms into an advantageous situation. Mechanisms to achieve such an advantage can mainly be found in the open innovation literature. In particular, external knowledge sourcing may be used systematically to achieve an effective lead-time advantage over rivals' products. The *first chapter* shows, based on a combination of firm level Community Innovation Survey (CIS) and patent application data, that firms with a closed development process are having a harder time to profit from lead time advantages. Firms directing their external knowledge sourcing strategy towards customers,

suppliers, and science are benefiting from more effective appropriation by means of lead time advantages. Furthermore, I find positive returns to the efficiency of using lead time advantage for appropriation from both breadth and depth of the external knowledge sourcing strategy but the effect decreases as firms reach their absorptive capacity.

Chapter II explored whether patents function as intended by policy by re-visiting the seminal framework on knowledge leakage by Mansfield. Theoretically, patents should provide protection from imitation. In return for a temporary monopoly on the protected invention, the patentee forgoes on secrecy by disclosing the functionality of the invention to the public in the patent document. In the *second chapter*, using data from the Flemish R&D survey and the PATSTAT patent database, we find that SMEs that are heavily engaged in patenting are being less confronted with imitation. The effect of patents on the dissemination of R&D is, however, insignificant. Therefore, we conclude that patent disclosures do not significantly harm the 'appropriability conditions' for inventions, but help to protect, at least partly, against imitation, as it has been originally envisaged by policy.

Chapter III contributed to the economic literature on patent litigation by taking a new perspective. In the past, scholars mostly focused on specific litigation cases at the patent level and related technological characteristics of the invention to the event of litigation. However, from a firm level perspective, observing the economic reality of IP disputes suggests that not only technological characteristics may trigger litigation suits, but also the market positions of the firms. Finally, in the *third chapter*, using a combination of CIS and PATSTAT data, I find that when controlling for the importance and quality of a firms' IP portfolio, the composition

of turnover in terms of innovations and imitations has additional explanatory power regarding litigation and could thus constitute an important (omitted) variable in future studies on the topic. Firms, considering legal enforcement of their IPRs to safeguard their appropriation position, seem to act upon more than just technological value of the underlying inventions, they crucially take into account the market value and act according to the stakes involved.

The research presented in this thesis does not come without limitations however. Since the Flemish CIS and R&D data cannot effectively be combined into a panel, because of the randomness in the sampling procedure, an analysis that controls for time-invariant unobserved heterogeneity was not possible. The cross-sectional nature of my analyses also makes simultaneity bias a potential issue since several of the variables could not be lagged. However when the information was available, and in particular for some of the main regressors of interest in Chapter II, lagging was possible since the information stemmed from administrative sources where firms were observed several times. Given the self-reported nature of the CIS and R&D data, one could also be concerned with issues regarding measurement error. I argue here that by merging in and using additional data from other administrative sources, the concerns are probably mitigated. Indeed, my main effects are robust to stacking these additional variables into the analysis and the effects I find are in line with the existing literature.

This thesis shows that combing survey with administrative (patent) data is, indeed, a fruitful avenue for research in the field of economics of innovation and IP. In the three chapters of this thesis, I contributed to the field by applying a modern empirical lens to three issues of contemporaneous importance. I find that both formal and informal IP can lead to better

appropriation for firms and therefore suggest that governments aiming to support innovation in the long run should make several considerations in implementing their policy mix. On one hand, providing incentives by granting temporary monopoly rights is probably indispensable, on the other, stimulating knowledge sharing and network building might be just as important. The main challenge here lies in reconciling two conflicting aims, i.e.. 1) ensuring companies can reap the fruit of 'their' labour, and 2) stimulating firms to share their intellectual capital. To do so, another consideration for government is setting-up and adequate licensing and co-ownership systems where firms can flexibly share the returns to their innovation and R&D investments. Because of its costly nature and because of the tendency of firms to more fiercely protect their rights when the stakes are high, litigation can best be considered as a second best outcome. Given that most modern western economies in the globalized world operate under conditions of openness and innovative competition, like it is the case in Belgium, I argue that with adequate caution, my results are of interest to a wider geographic audience. Further opportunities for research on this topic lie in testing the robustness of my results for a broader scope of economies, i.e. for example more closed and less innovative. Opportunities also lie in combining CIS and R&D data with more IP data stemming from other administrative sources, i.e. data on trademarks, copyrights and industrial designs.

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