Master Thesis Corporate Finance

Department of Business and Management

To what extent did the 2008 Dutch Patent Law Reforms affect Dutch R&D Investments?

Empirical Evidence using a Difference-in-Difference Approach

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Academic year	2018/209

Abstract[1]

This study investigates to what extent the Dutch patent law reforms enacted in 2008 affected Dutch R&D investments. The reforms aimed to increase legal certainty, reduce translation costs and improve patent awareness. Given the relationship between innovation through patents and R&D investments is endogenous this study addresses this issue in several ways. To investigate to what extent the 2008 Dutch patent law reforms affected Dutch firms' R&D investments, the empirical strategy builds on a Difference-in-Differences (DD) approach combined with a Fixed Effects estimator, which is designed to address the endogeneity issue relating to the patents-performance relationship. Based on the assumption the Dutch Government passed the enacted Patents Act independently of Dutch firms, I compare the difference-in-differences between Dutch firms in a pre- and post-2008 period with a group of control countries composed of Belgium, Germany and France. Drawing from 8 years of data from the European Patent Office (EPO), I show with a DD estimation Dutch patent owners did not file fewer patents after the reforms, but also before. Using firm level accounting data from Bureau van Dijk (BvD) for the same period, the data show when controlling for time-variant firm characteristics, the reforms did not induce Dutch firms to spend more on R&D. Additionally, I show the parallel trend assumption is unlikely to hold. That is, unobserved factors might at least partially drive the findings of the analysis and consequently threaten the internal validity of this research. I then perform subsample analyses to investigate heterogeneity across (1) firm size and (2) the way firms and industries develop and use technology using the Revised Pavitt taxonomy. There is only weak evidence the amended Patents Act had a different effect on large firms than on SMEs. It is however not unlikely this is due to a small representation of SMEs within the sample. Based on the data, only the most as well as the least R&D intensive industry clusters invest less in R&D in the post-reform period. Similar to the other analyses, the industry cluster subsample analysis is subject to a parallel trend violation. Because there is only weak statistical evidence, I argue there is not enough evidence to conclude the 2008 Dutch law reforms significantly affected firms' R&D investments.

[1] An extended summary can be found in appendix 3

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1. Theoretical Background

This section precedes the empirical part and outlines the theoretical context of this study. Since the theoretical scope lies on the relationship between innovation and patents, the rationale behind the use of patents is explored. First, the main rationale of using patents to spur innovation is discussed. The following questions guide this section. Under which conditions is the use of patents justified? What are shortcomings of the patent system? Are there alternatives to the patent system and when are they more viable? This chapter then moves on with a discussion of the role of patents in innovation. Finally, heterogeneity within firm size and across industries are discussed in more detail.

1.1. Innovation incentive systems

The main question of this study assumes patents should affect innovation. This assumption is based on the idea that the provision of intellectual property rights to companies spurs innovation. Before moving on to this main question and proceeding findings, it is worthwhile to first discuss the IP incentive system and put the underlying assumption under question.

Why would we need an incentive scheme at all? Already in 1962, Arrow made a strong case for rewarding innovation. Every invention contains information, where information is a public good. For example, an Italian cafeteria or a more technically involved invention like an espresso machine able to produce several different kinds of coffee is costly to the inventor in terms of tangible parts as well as the information or knowledge on how to manufacture it. For the coffee device producing rivals however, already familiar with ways of manufacturing different kind of coffee machines, the costs of replicating the invention will mostly be born in its tangible elements. This in turn puts the inventor in a competitive disadvantage in terms of gaining a profit from commercializing the invention (the competitor imitating the product does not incur the development costs). Without means to compensate for this disadvantage, companies are disincentivized to invest in inventions at all.

Having established a case for the use of an incentive system to foster innovation, moves the discussion to question how this incentive should look like. Among the alternatives, there is the patent, which is defined as the exclusive right to market an invention for a fixed period of time. Patents are a form of Intellectual Property (IP), which includes copyrights and other forms of legal protection as well. Another definition of a patent is provided by Lehman (2003, p.2): *“patents are exclusive property rights in intangible creations of the human mind”*. Lehman (2003) further defines the patent by noting that *“patents exist only as provided in the laws of sovereign states and can be enforced only to the extent that application has been made and a patent granted covering the territory of an individual state”*. Furthermore, patents are characterised by a finite duration, with a general global average of about 20 years. Finally, patents need to meet certain requirements of newness, usefulness and non-obviousness, which is discussed in more detail in the empirical part. The procedure where the patent authority checks whether these requirements are met is called examination for ‘prior art’.

Gallini and Scotchmer (2002) distinguish two alternative incentive schemes to IP. These two alternatives entail schemes the use of ‘prizes’ and/or ‘procurement’. A prize could entail an a priori determined monetary reward for the development of an invention out of tax-payers’ money. This reward can be assigned to individuals or firms, conditional on delivering the invention.

Alternatively, a procurement process can be set up to incentivise firms to develop inventions. For example, a ‘fixed-price’ contract can be drawn up, where the government pays a company the develop an invention. Without any modifications, this type of contract bears the potential risk of moral hazard. This implies that the developer or agent has an incentive to just receive the price and do anything but successfully develop the invention. This moral hazard issue can be tackled by staging the reward, based upon milestones related to the invention’s development. In the procurement system, the right to develop the invention can be distributed through an auction. This way, the issuer (here, the government) can ensure the invention is developed at a competitive price.

Comparing both the ‘price’ and ‘procurement’ mechanism to IP, one could argue the former two systems are the most preferable and logical choice in the case where the issuer has perfect information. That is, to the issuer, it is a priori completely clear how great the social benefits are and what cost is carries to realize those benefits. In the case of IP, determining the requirements of the invention is left up to the (private) developer, which would make most sense if the developer has a greater capability to determine those requirements. Concluding this first comparison, price and procurement systems are preferred to an IP system when the issuer is able to adequately estimate the costs to and benefits of the innovation.

Next to this, if an IP system is used in the case of imperfect information, the danger of moral hazard arises, because the objectives of the developer could diverge from the issuer’s. The issue could arise as follows. Consider leaving the choice in which invention to invest at the discretion of private companies. This provides them with the possibility to screen investments. Because of competitive forces, the company is incentivised to use this screening ability. As the company management’s objective is to maximize firm value, it will choose the investments best fitting this objective. This objective might or might not overlap with society’s best interests.

The above raises the question: in which case is IP the preferred innovation incentive mechanism? Gallini and Scotchmer (2002) distinguish three layers in the process to decide which mechanism is most applicable; (1)

the decision problem, i.e., should a project be initiated at all, (2) the delegation problem, which firm(s) should develop the project and lastly (3) the funding problem, how to determine the appropriate reward.

Regarding the decision problem, based on theories about signalling and asymmetric information, it can be argued the procurement system is not the most efficient. The key issue here is that, if one firm invests in development, to the other observing firm it is at that point unknown whether it does so because it can deliver either high value for high or low costs, or low value for low costs. Not being able to adequately compare the value propositions, the observing firm could be withheld from investing. Moreover, firms can be wrong in their (ex-ante) expectations of their final value delivery. This discussion highlights the flaws of a procurement system, but this does not by definition imply the IP or price system are the second best alternatives.

In order to tackle the delegation problem, it is necessary to mitigate the (first) decision problem, so it is established that there the sponsor will actually invest. Here, Gallini and Scotchmer (2002) state the auction mechanism works best in the case when to sole issue is to identify the most efficient firm (costs and benefits can be estimated and observed accurately). The simple price system is preferred when there is only one firm in the market capable of undertaking the innovation project. The authors further argue in this case that, when the public sponsor sets the monetary price amount equal to societal benefits, the firm's investment policy is aligned with social utility. I argue that, though matching the price with social benefits may in fact be a valid argument for using the price system as an innovation incentive mechanism, firms still have the ability to screen investments and either invest elsewhere or will bargain based on their monopoly position to get the highest return.

One assumption underlying Gaillini and Scotchmer's (2002) theory is that IP (inherently) reflects social value. However, there is a significant body of literate (e.g. Macdonald, 2004) arguing the strategic value of patents – especially in some industries – exceeds the value of commercializing it directly to contribute to society through innovation. Following this logic, IP and patents in particular, mainly serve as innovation impediment instead of an accelerator. This contrasting view on the relation between patents and innovation is further discussed in paragraph 1.2.

From another point of view, Bessen and Maskin (2009) contribute to this view on patents as well. They show, using the change in patent protection in the US software industries in the 1980's as an experimental setting, firms in exactly that industry showed stagnating and even lower levels of R&D investments thereafter. They authors explain this by arguing that, if the inventions are 'complementary' and 'sequential', innovation is benefits from a lack of IP protection. In this context, 'complementary' means that the invention takes a slightly different research angle and 'sequential' refers to the fact the invention is an extension of a previous invention. Their reasoning is that knowledge and ideas available at competing companies cannot be transferred into products or services, which slows down the innovation process. One could argue the patent holder could easily benefit from this situation by drawing up a commercially attractive licencing agreement with a competitor. However, according to Bessen and Maskin (2009), profit-dissipation due to increased competition following from this licencing agreement is highly likely to outweigh the benefits of it, which results in the company making the society harming decision not to engage in a licencing agreement at all.

1.2. The role of patents in innovation

According to Agostini et al., (2015) a patent provides the inventor with the exclusive right given to them by law to use and exploit their inventions for a limited period of time. Because patents have been used frequently in the literature to proxy innovation (e.g. Grilliches et al., 1990; Austin, 1995), the relationship between innovation and firm performance is often studied considering innovation from the perspective of patents. This is done because patents contain very detailed information about inventions and because patent data are more easily available than other innovation related data on companies (e.g. entrepreneurial spirit) Agostini et al., (2015). Moreover, patents have the favourable feature that, their international standards are relatively homogenous across countries (Danguy & De Rassenfosse, 2010). But, before directly (and naively) assuming every patent is an indicator of innovative activity, the terminology should be considered in more detail. Ernst (2001) provides a clear distinction between innovation, inventions and patents. This distinction leads to three caveats regarding the use of patents as proxy for innovation.

First, not all inventions are patentable. Sometimes inventions do not meet the criteria to be patented. In order for a patent to be granted it must be (1) novel in a legally defined way, which means in European countries: first-to-file, whereas it means in the US: first-to-invent. Moreover, the patent has to be (2) nonobvious. This means a highly skilled professional in the specific are of the patent would need the patent in order to achieve the same output. And finally, the patent must be (3) useful in a sense that allows for commercialization of the patent (Hall, Jaffe & Trajtenberg, 2005). The point is that inventions which are not patentable can in fact create value. After the 2008 Dutch patent law reforms, exactly the three criteria outlined above become applicable to all new patent filings (where before 2008 meeting these criteria could be avoided by filing a 'small' patent). I adopt the Netherlands Enterprise Agency's (2008) expectation that requiring all patents to meet the three criteria above increases legal certainty. Moreover, Bloom and Van Reenen (2012) show that if a government's policy is successful in increasing legal certainty, this should increase productivity in knowledge capital.

Second, not all patentable inventions are patented. Whether to file patent or not is a strategic decision (Hall, Jaffe & Trajtenberg, 2005). The strategic consideration can be not to file the patent to maintain discretion regarding the invention. Another strategic consideration is to file the patent first (before other market players do), aiming just to own the patent and potentially delay innovation. The intuition behind this is discussed further ahead in this section. Furthermore it is important to distinguish between inventions and innovation. Inventions focus on the development of new ideas, whereas innovation relates to the development of commercially viable products or services from creative ideas (Artz et al., 2010).

Third, the economic value of inventions as well as patents vary substantively. That is, only a very small percentage of the distribution of inventions and patents are (1) extremely valuable and (2) actually commercialized up to this full value potential. The reason for this is the distribution of innovation success is highly skewed. Only a small number of innovations is highly valuable. Taleb (2007) describes this phenomenon using a theoretical world he calls ‘Extremistan’. In this theoretical place, inequalities are such that one single observation can disproportionately impact the aggregate, or the total (Taleb, 2007). Entities within this world are thus characterized by a high degree of unpredictability (like academic citations, only very few scholars get the large majority of all citations). In other words, there are variables where the outcome does not fit a normal distribution (for example, human age or length do fit the normal distribution). I argue the economic value and ability to commercialize them up to their full potential are both variables belonging to ‘Extremistan’. This makes investing in patents a risky venture, thereby making a case for strategic patenting. Concluding this argument, because unpatented innovation is more difficult to measure than patented innovation, patented inventions still form the best or most measurable expression of innovation input, but it has its limitations.

Following the argument in literate that R&D investments by (private) firms are an investment activity and patent citations can be used to measure its success (Hall, Jaffe & Trajtenberg, 2005; Hall, Mairesse & Mohnen, 2010), I argue that if a change in patent law affects firm performance it is likely to affect R&D investments as well. The latter statement is based on Hall, Jaffe & Trajtenberg’s (2005) findings that the market values R&D ‘success’ in terms of patent citations. Patented innovations belong to the intangible assets of a firm. Firms generate patented innovations by investing in R&D. If, everything else equal, the legal climate for filing patents changes, i.e. if reforms enacted by a government encourage or discourage firms to file patents, I argue this provides firms with incentive to reconsider their R&D investment policy. Some evidence for this relationship is provided by Artz et al., (2010). They find a positive relationship between patents and R&D and explain this result by arguing internal research capabilities are key in enabling a firm to generate creative outputs (Artz et al., 2010).

1.3. The relationship between patents and firm performance

To which extent patents relate to firm performance is not a new question in the literature. Already in 1965, studying 365 firms from the USA Fortune 500, Scherer evaluated the impact of the number of patents granted on profit, sales growth and profit ratios. Between patents and sales growth Scherer (1965) finds a positive relationship. Profit ratios did however not increase significantly. Accounting for the endogeneity issue which is also introduced later in this study, the author uses a time lag of four years between patent grant and subsequent yearly success. Some years later, applying a potential time lag up to three years after the invention is patented, Comanor and Scherer (1969) find similar results focussing on the pharmaceutical industry. For this purpose, they analyse panel data using fixed effects. Extending the definition of performance with a market-based measure, Griliches et al., (1991) use event study methodology and find present and past patent applications explain five percent of the variance in market value changes. Contrasting Griliches' et al., (1991) findings, Austin (1995) studies twenty biotechnology firms in the USA and finds a positive effect of patents granted on market value. Ernst (2001) incorporates a time lag of two – three years and finds an increase in sales within fifty (SME) German machine tool manufacturers. Ernst (2001) argues European patents are of higher quality than national patents and observes a higher impact on sales within European patents. In summary, though there is a substantial body of research providing evidence for a positive relationship between patent and firm performance, other studies disagree with this statement.

Following up on the studies above presenting mostly no or positive relationship between patents and performance, a more recent stream in the literature brings forward other arguments making a case for the negative results. Though fully agreeing with the statement firms must pursue innovation to improve profitability, Artz et al. (2010) find a negative relationship between patent filings and both sales growth and Return on Assets and explains his result using the phenomenon 'strategic patenting', where patents are employed as 'strategic weapons'. This idea is supported in the literature, especially by Macdonald (2004) explaining the large increase in US patents since the 90s had little to do with innovation but more with blocking competitor's competition efforts. This transforms the role of a patent from a mean to encourage innovation to a 'competitive positioning' mechanism (Artz et al., 2010).

Nguyen (2007) makes an even more convincing argument for a negative innovation-performance relationship as she describes the existence of 'patent holding shells' which are entities established merely to treat operating entities (i.e. firms that actually do commercialize innovations) aggressively with infringement litigations. The harnessing of strategic weaponing and to a larger extent, employment of patent holding shells in an offensive way are market inefficiencies which may have a strong restraining effect on the innovation-performance relationship in reality. In another recent study, Artz et al. (2010) find a negative relation between the number of patents and the Return on Investment. They point towards the rise of strategic patenting as potential explanation of their findings. Based on the arguments made above summarizing reasons why more patents do not lead to more innovation (or even the contrary), I argue that if the Dutch patent law reforms induce firms to invest significantly more in R&D but Return on Assets or Return on Equity does not increase as well, this could be an indication of strategic patenting behaviour. This expectation matches Artz's (2010) findings discussed earlier in this section.

Regarding the tendency not directly commercialize the filed patents, Ernst (2001) notes that in industries where patents provide effective protection, firms are more likely to actively patent inventions or purchase them from the market. An example of a patent-active industry is the pharmaceutical industry (Macdonald, 2004). According to this observations by Macdonald, (2004) I expect a potential Dutch patent law effect to demonstrate itself in a stronger way within the pharmaceutical industry compared to the average of other industries.

1.4. The Special case of the SME

Whereas large firms have the financial resources to their disposal to employ a strategy of strategic patenting, SMEs face relatively higher costs in acquiring and enforcing patents and therefore, employing such an anti-competitive strategy could be too costly resulting in a different patents-innovation relationship. However, SMEs differ from large firms in a sense that they have shorter lines of communication, relatively informal decision making and more flexibility, which provides them with an advantage in realizing more rapid innovation compared to large firms (Maravelakis et al., 2006).

Performing telephone interviews among Taiwanese SMEs, Yeh-Yun Lin & Yi-Ching Chen find only a weak relation between innovation and firm performance. In fact, Agostini et al. (2015) worked on the innovation-performance relationship as well, but in an Italian SME context using patents and report no strong relationship between patents and/or patent quality with firm performance. As possible explanation, they present Holgersson's (2012) findings that the main reasons for entrepreneurial firms not to issue patents are because of financing (e.g. attracting venture capital). Moreover, as the impact and associated financial benefits of patents cannot be a priori determined, SMEs might be reluctant in using property protection when conducting business, making an argument against a positive innovation-through-patents-innovation relationship. For these reasons, I argue the level of uncertainty involving the choice to file a patent as well as to commercialize them is more severe within SMEs than within large firms.

1.5. Heterogeneity across industries

As stated earlier, the role of patents and innovation differs among industries. Focussing on exactly this varying role of innovation among industries, considering the Pavitt 1984 taxonomy is relevant. In particular, the Revised Pavitt taxonomy (Bogliaciano & Pianta, 2016), which is adapted to the NACE 2 revision, provides a useful framework to describe the role of innovation on the industry level. The Revised taxonomy classifies NACE sectors as follows; (1) Science-Based (SB), focussing on the industries relying most heavily on R&D, that is, this category includes sectors where innovation is based on science and R&D together with a high propensity to patent. This class includes among others the pharmaceutical industry, electronic industries and telecommunications. The next category is (2) Specialized Suppliers (SS), which denotes the sectors producing machinery and equipment. Importantly, the key source of innovation in this industry cluster are tacit knowledge and design skills, embodied in the labour force. Here, R&D is still relied upon, but in terms of priority to obtain innovation output it is inferior to tacit knowledge. Among others, this category includes real estate activities and legal and accounting activities. In (3) Scale and Information intensive (SI) sectors, firms focus predominantly on scale economies and standardization of the production process. Consequently, innovation is mostly incremental as changing the process comes at a high cost. Typical examples within this category are the automotive industry and financial service activities. The last category entails (4) Suppliers-Dominated (SD) industries, includes the traditional, less innovation reliant sectors. Typical examples are the food and textile industries. They acquire innovation through inputs and machinery from other sectors. Concluding, the industry clusters are ranked ordinally from high R&D intensity and propensity to patent in (1) to less reliant on R&D and characterized by a low propensity to patent (4).

2. Introduction to the empirical part

This section outlines the empirical question brought forward in this study. Extending the theoretical framework with an empirical context this research continues with an empirical study. To what extent did the 2008 Dutch patent law reforms have an effect on firm innovation? The Dutch government aimed with the amended Patent Act to increase legal certainty, reduce translation costs and to improve patent awareness. The reforms were enacted already ten years ago, but this question remained unanswered.

Patents provide inventors with intellectual property protection. Though not all innovations are patented, patents still remain a useful way to measure innovation, because (1) they contain highly detailed information about the invention, and (2) they are more measurable then alternatives (Agostini et al., 2015). However, it remains a challenge to disentangle the effect of innovation through patents on innovation because the economic value of patents is highly skewed and only a small percentage of patents is truly valuable (Scherer and Harhoff, 2000). Some studies addressed this issue by applying quality-weighted measures for patents (e.g. Ernst, 2016; Agostini et al., 2015). However, the application of different ways to account for patent quality does still not address the fact the relationship between patents and firm innovation is endogenous.

This endogeneity issue can be explained intuitively. Suppose we only know and the number of patent filings by a firm and R&D investments are positively related. In this case it could be that the firms succeeding to use R&D activities to patented innovations benefit in terms of firm performance. However, it can also be the case that only firms with certain technological capabilities or financial resources file almost all patents but would have performed better than competitors anyway. Moreover, it is already established that patents are not equally important across industries (Macdonald, 2014). Without acknowledging the presence of possible heterogeneity across industries – especially when drawing a sample dominated by firms in patent-active industries such as the pharmaceutical industry (Shulman, 1999) – one might draw the false conclusion patents do affect innovation across the board. As mentioned before, only a small fraction of patents account for a large share of value of all patented innovations. As a consequence, R&D investments aimed on commercializing patented innovations are highly risky, not to mention the potential information asymmetries and agency costs that arise when investing in an intangible asset such as intellectual property rights (Hall & Oriani, 2006). Especially for this reason, the causality question from patents to innovation deserves the necessary attention.

Several studies addressed this endogeneity issue allowing for a time lag from two up to four years between invention or patent grants and subsequent firm performance (e.g., Ernst, 2001). Though this approach makes reverse causality less likely, endogeneity is still not fully accounted for (Bellemare, Masaki & Pepinski, 2017). Of particular interest in this patents – innovation relationship are Small and Medium size Enterprises (SMEs). This particular type of firms is considered to be an important innovator in many industries (de Rassenfosse, 2012). Moreover, the literature provides evidence that SMEs increasingly use patents (e.g. Jensen & Webster, 2006). However, due to earlier mentioned uncertainty regarding intangible assets such as patents (Hall & Oriani, 2006), especially SMEs which face more financial resource constraints than large firms are disadvantaged in their ability to acquire and commercialize patents.

To investigate to what extent the 2008 Dutch patent law reforms affected Dutch firms' performance, the empirical strategy builds on a Difference-in-Differences (DD) approach combined with a Fixed Effects estimator, which is designed to address the endogeneity issue relating to the patents-innovation relationship outlined above. Based on the assumption the Dutch Government passed the enacted Patents Act independently of Dutch firms, I compare the difference-in-differences between Dutch firms in a pre- and post-2008 period with a group of control countries composed of Belgium, Germany and France. These countries are geographically close, economically integrated, and share the same currency as Dutch firms. They are therefore assumed to be subject to the same macro-economic shocks as Dutch firms. Yet, these countries did not pass similar patent law reforms right around 2008.

Drawing on patent panel data from the European Patent Office (EPO) for the period of 2005-2012, I show with a DD estimation Dutch patent owners did not file fewer patents after the reforms, but also before. To further identify the effect of the 2008 Dutch patent law reforms, firm level accounting data for the same period are collected from Bureau van Dijk (BvD). Again using a DD estimation, the data show when controlling for time-variant firm characteristics, the reforms did not induce Dutch firms to spend more on R&D. Moreover, I show the parallel trend assumption is unlikely to hold. I then perform subsample analyses to investigate heterogeneity within firm size and across industry clusters, based on the aforementioned Revised Pavitt taxonomy. Then, I test for specific lagged effect for one up to four years. The results close with an additional model dedicated to the pharmaceutical industry.

There is only weak evidence the amended Patents Act had a different effect on large firms than on SMEs. It is however not unlikely this result is due to a small representation of SMEs within the sample. The industry cluster subsamples generate an ambiguous result. Average R&D levels move in different directions for different clusters, at a marginal significance level of five percent. Then, for the sake of completeness, the data using lagged depended variable models. Due to the aforementioned parallel trend assumption violation, I interpret the significant outcomes as a stronger economic crisis effect hitting Dutch firms than control firms. A final subsample analysis of the pharmaceutical industry shows Dutch pharmaceutical firms decreased R&D investments after the patent law reforms. Because the evidence is not statistically robust I argue there is not enough evidence to conclude the 2008 Dutch law reforms significantly affected firm innovation.

The contributions of this study are twofold. First, using a quasi-experimental design, an evaluation of the effect of Dutch patent law reforms on firm innovation is provided. Second, by integrating the reforms in a theoretical context, this study draws additional attention to the unresolved endogeneity issue regarding the relationship between patent filings and innovation. We now continue by introducing the 2008 Dutch amended patent act, the empirical context of this study.

2.1. The 2008 Dutch amended Patent Act

After the EPO opened in 1978, the Netherlands Patent Office (NPO) saw a progressively decreasing number of patents filed in the Netherlands. The Dutch Government therefore decided in 1995 to switch to a patent system which granted all patents drafted by inventors without substantive examination, no matter the invention is patentable (Netherlands Enterprise Agency, 2008). The 2008 Dutch patent law reforms are based on a review of the 1995 Patents Act.

The key implications of the reforms

The Dutch patent law reforms in 2008 changed aimed to (1) increase legal certainty among all parties involved, (2) reduce translation for Dutch and international patent applicants and (3) improve patent awareness among all parties involved (Netherlands Enterprise Agency, 2008). The most important changes of the law regarding these three goals are outlined and interpreted below.

Increased legal certainty

By abolishing the six-year patent, the law reforms aim to increase legal certainty. Before 2008, when applying for patents, applicants could choose to request a ‘search of prior art’ or apply without such a report at all. If they did not choose for this search report, the patent’s term was six years. Moreover, in this case the patent was granted no matter the claimed invention was patentable. After the grant the Dutch courts had to decide on the patent’s validity (in case of objections). On the other hand, patent applications based on the ‘examination for prior art' had a term of twenty years. In a revision of the Dutch Patents Act, the Dutch government stressed the six-year patent induced unwanted uncertainty for both the patent proprietor and third parties. It is therefore abolished. As a result, after the Dutch patent law reforms, all new Dutch patent applications will follow the twenty-year patent application procedure. After the amended Patent Act, all new patents will require a search report and moreover, a written opinion of the EPO is included examining the relevance of the cited documents.

Additional to the 6-year patent abolishment, The amended Patent Act increases the role of the Netherlands Patent Office in proceedings for patent nullifications to increase legal certainty. Anyone can ask the NPO for an advisory report regarding the validity of a particular patent. The advisory report is made based on a third party's request. The Dutch court then usually concludes in accordance with the advisory report. Before the 2008 reforms, the NPO could only consider patent nullification based on arguments made in the third party's request. The amended Patent Act empowers the NPO to provide also additional arguments for nullification in the advisory report which are not included in the request but can be derived from the search report. This increases the scope of the NPO in compiling advisory reports regarding patent nullifications. According to the Netherlands Enterprise Agency (2008) this will increase quality of the search reports and nullification procedures and therefore increase legal certainty regarding Dutch patents.

Reduced translation costs

The amended Patents Act allows patents to be filed in English (expect for the claims, which still have to be in Dutch). Pre-2008 Dutch patent law required the complete patents to be filed in Dutch. As a reason for this, the amended Patents Act states filing in English is allowed to reduce translation costs for Dutch applicants when filing patents outside the Netherlands. According to the Netherlands Enterprise Agency (2008) this change is beneficial to both Dutch and international applicants filing in the Netherlands. As new Dutch patents can be used more easily abroad when filing international patents, the Dutch patent becomes more attractive. Especially SMEs are expected to benefit from these reduced translation costs. Based on this reform, the Netherlands Enterprise Agency (2008) expects an increase in the number of patents filed by foreign companies in the Netherlands. However, because the acceptance of Dutch patent applications in English is unilateral, Dutch firms might not yet benefit from reduced translation costs when filing internationally but could even be put at a disadvantage. For example, a Dutch firm can file a patent in English in the Netherlands. A French firm can file the same patent in English in the Netherlands. However, the Dutch firm cannot file this patent in France in English. In this case the patent would have to be translated into French. French firms therefore have to advantage that they can choose to file a patent in the Netherlands either in Dutch or in English. Dutch firms filing in France have only one choice. Again, this is expected to mainly affect SMEs (Netherlands Enterprise Agency, 2008).

Another implication of the reforms is that Dutch companies with an insufficient proficiency of the English language trying to avoid infringement of competitors' patents cannot directly read the entire content of the patent. The bearer of the translation costs becomes the Dutch firm instead of the international firm who is released from the translation requirement. According to the Netherlands Enterprise Agency (2008) this change will affect small firms rather than large firms. It is therefore not clear whether Dutch SMEs will either benefit from reduced translation costs because filings outside the Netherlands are allowed to be in English or suffer from the fact descriptions of claims in new patents are allowed to be in English.

Improved patent awareness

The law changes aimed to improve patent awareness include the movement of the first annual fee from the fifth year after the patent filing date to the fourth year after the patent filing date. The annual fees are increase progressively as the patent ages. Shortening the no-fee period by one year provides patent owners with a higher incentive to assess the necessity to maintain their patents. Netherlands Enterprise Agency (2008) states 3 years is sufficient to fully explore the commercial potential of a patent. The amended Patent Act is therefore not expected to negatively affect patent owner's ability to assess the commercial probabilities of a its patents. The annual fees start from a few tens of euros the first year, al increasing to approximately 1.5 thousand euros in the 20th year. Moving the annual fee one year earlier should decrease the number of unused patents held by Dutch firms because holding the same patent for the same time after the law reforms is more expensive than it used to be before the reforms.

The remaining of this study is organized as follows. First, the next introduces the Dutch patent law reforms and places them and this study in a theoretical context. Second, the subsequent sections address the empirical strategy and describe the data. Third, the results are presented, linking innovation through patents to firm performance. Fourth, a conclusion is provided. Fifth and finally, a discussion of results, limitations and new research avenues are presented.

3. Methodology

3.1. Empirical strategy

To aim of this study is to investigate to what extent the Dutch 2008 patent law reforms had an effect on Dutch R&D investments. Because the relationship between patents and innovation is potentially endogenous, the effect due to the patent law reforms can only be observed when isolating potential confounders. To pursue this goal, I combine two established methods both used in the corporate finance literature to get the optimal result. First of all, I use a Difference-in-Differences (DD) approach. Using an quasi-experimental setting, this method allows to identify cause-and-effect relationships (Roberts & Whited, 2011). The second method entails the addition of the Fixed Effects estimator to the DD estimator, which allows to rule out the effect of (un)observed time invariant effects. Combining these two methods, the effect of potential confounders is mitigated in several ways. This section will now further introduce the research design techniques and discuss internal validity. I then introduce the patent data and accounting data. This chapter closes with a discussion of parallel trend assumption.

The Difference-in-Differences approach

The intuition behind the DD approach can be explained as follows. Suppose the aim is to estimate the effect of the patent law change in the Netherlands in 2008 on R&D expenditures of Dutch firms. In order to do this, R&D expenses by Dutch firms after 2008 would need to be subtracted from their R&D expenses before 2008. However, other factors in 2008, e.g., the economic crisis, may have affected these Dutch firms along with their tendency to invest in R&D. Including a control group, i.e., German, Belgian and French firms, allows to control for changing economic conditions, under the assumption that the control-country group is affected in a similar way by the economic crisis. In this case, the change in the control firms' performance would be a measure of the crisis' severity. Therefore, to isolate the treatment effect, differences in firm performance before and after 2008 of Dutch firms are compared to the differences in firm performance in control countries before and after 2008. The difference of those two differences serves as the estimate of the Dutch patent law effect in the Netherlands.

If assignment to either the treatment country (the Netherlands) or the control countries (Belgium, Germany and France) is completely random, both observed and unobserved confounders are balanced across the treatment and control group, which results in potential confounders on average being uncorrelated with the treatment assignment. This in turn provides an unbiased estimation of the treatment effect. In fact, the validity of the DD estimation only holds if pre-treatment trends between treatment- and control group do not differ significantly. This is called the parallel trend assumption (Roberts & Whited, 2013) Testing for this assumption substitutes for randomization. That is, if pre-treatment trends in outcome variables do not differ significantly one could argue no relevant systematic differences between treatment- and control group are present.

Using the patent law changes in the Netherlands in 2008 as a treatment effect this study aims to mimic the design of a randomized controlled trial as closely as possible. The underlying assumption is the patent law change is exogenous or plausibly unconfounded (i.e., independent of the outcome variables). More specifically, I assume Dutch firms did not collectively influence the Dutch government's decision to enact the patent law changes in 2008.

One way to account for possible differences on the firm level is to control for them. Similar to Agostini et al. (2015) in estimating the effect of patenting on (SME) performance, I control for firm size. The time variant controls for firm size are Total Assets and Number of Employees. The model below presents the DD model as described above. Time variant firm-level controls represent total assets and the number of employees. Additionally, country- industry- and year fixed effects are included.

$$R\&D\ Expenditures = \alpha_i + \beta_1 Post_{it} + \beta_2 NL_i + \beta_3 Post_{it} * NL_i + \beta_4 Total\ Assets_{it} + \beta_5 Number\ of\ Employees_{it} + \beta_6 Country\_dummies_i + \beta_X Year\_dummies_t + \beta_Y Industry\_dummies_i + a_i + u_{it}$$

Where subscript "i" indexes firms and "t" indexes year. If factors other than the treatment (e.g., the 2008 economic crisis) would have an effect on the outcome variable, this would be reflected in "β_1", the coefficient on the post-treatment period. If Dutch firms in general have different levels of the outcome variable than the control group, this would be reflected in "β_2", the coefficient identifying the treatment group. If the patent law reforms have an effect this is reflected in "β_3". Using this approach, unobserved heterogeneity is eliminated on the country and the post-treatment level. This quasi-experimental method is proven in empirical business research (Roberts & Whited, 2013; Bertrand & Mullainathan, 2003). Note that the error term is split up in a time invariant component "a_i" and a time variant component "u_{it}" distinguishing different types of potential confounders. This distinction is discussed below.

Applying the Fixed Effects estimator

Taking the elimination of potential confounders even further, the unobserved heterogeneity (a_i) is considered not only at the country level but at the firm-level as well. Firms can (and probably they do) differ on individual level, e.g., one firm can be more effective in commercializing innovations than another firm (assuming this ability is constant over time, which could be expressed in a more or less effective CEO serving a company for several years). Or alternatively, firms can differ in their ability to access additional capital required to innovate, which makes it more difficult for some firms to achieve innovation than for others. Both examples will have an effect on the performance of the firm. The FE transformation removes these firm fixed effects from the error term. This allows to relax the assumption that all firm fixed effects are controlled for.

The reason behind removing the firm-fixed effects from the error term is as follows. Unobserved time invariant effects correlated with the outcome variables might be present, and if this is the case, they bias the estimation of the treatment effect. The so called Fixed Effects estimator allows to observe the difference within firms over time instead of across firms. This allows to observe a firm's changes over time, with this same firm at an earlier point in time as control (firm). For this reason, the FE estimator is also called the within estimator. In order to obtain this estimator, all observations are subtracted with their means (which eliminates all time invariant factors). This results in the following general model.

$$R\&D\ Expenditures = \beta_1 Post_{it} * NL_i + \beta_2 Total\ Assets_{it} + \beta_X Number\ of\ Employees_{it} + \beta_Y Year\_dummies_t + u_{it}$$

Where additional year-treatment interaction variables can be created to model the change within Dutch firms over time. Note that the treatment effect would in this model be reflected in "β_1". In order to address the question to what extent there is a treatment effect and to what extent this effect is present among Dutch SMEs, several regressions are carried out using both year-treatment interactions and the post-treatment interaction.

In order to further establish internal validity, this study refers to guidelines provided by Roberts and Whited (2013). Drawing from this list, three tests are of particular interest in accounting for unbiasedness and consistency; (1) the repetition of the DD estimation on pre-treatment years to exclude alternative (unobserved) forces, (2) the replacement of the dependent variable with control variables to make sure the controls are unaffected by the treatment effect. Finally, (3) the evaluation of the timing of behaviour changes over time, which is relevant due to the potential lag of approximately three years in the effect of patent filings on firm performance (Hall, Mairesse & Mohnen, 2010; Ernst, 2001). Effects further away in time from the actual treatment event are more sensitive to other confounding factors which could threaten the study's internal validity. This study uses eight years of panel data which allows to model these lagged or delayed effects.

Betrand, Duflo and Mallainathan (2004) already raised the issue that often in DD analyses, standard errors are too low, leading to artificially inflated t-values and very low p-values accordingly. Therefore, robust standard errors are clustered at the industry level. This choice has two reasons. The theoretical argument is that across industries the preference to be patent-active is heterogenous (Ernst, 2001). The technical reason is that though one could argue the countries are the key source of variation in the analysis, the clustered standard errors will only converge to the true standard errors as the number of clusters increase. Country-level clustering provides with only four clusters. Therefore, clustering on the industry level is preferable, as it provides with more clusters. Moreover, taking the standard errors into account is important in order to prevent type I errors. That is, rejecting the hypothesis the coefficient is indistinguishable from zero when it actually is not. Clustering the robust standard errors at the sector level allows to relax the assumption observations are independent within each industry. Whereas Panier, Pérez-González & Villanueva (2012) cluster robust standard errors on the country level when estimating DD, they justify this by recomputing the standard errors using a large group of control countries and clustering the errors at country and industry level. Moreover, in re-estimating the errors, the authors apply a nearest neighbour matching procedure which makes it even less likely country-level differences drive the result. As for this study these extra control country data are not available, the conservative approach of clustering the errors at the industry level is used.

3.2. Data description

Patent data

Patent data are obtained from the European Patent Office (EPO) PATSTAT database. PATSTAT contains bibliographical and legal status patent data on a global level. For the purpose of this study, annual patent level data from 2005 – 2012 related to patent owners within Belgium, Germany, France and the Netherlands are obtained. Whereas the value of using these data is substantively higher when successfully merging them with accounting data, due to technical constraints this merge could not be established. Using the EPO data, an annual patent count variable per patent owner is be obtained. How this variable is defined is shown in table 1. Moreover, this table shows I use the logarithmic transformation of this patent count variable. The reason for this transformation is the level version of this variable is highly skewed (many patent owners filed only one patent) and next to this, using the logarithmic transformation makes the result less sensitive to outliers (Wooldridge, 2015). Because the data contain patent filing dates and country codes, the data allow to apply the DD estimator controlling for year fixed effects.

Accounting data

Using Bureau van Dijk's (BvD) Orbis database, firm-level data panel data for the period of 2005 – 2012 are obtained. See table 1 for an overview of the variables used. From this data provider, all variables as defined in table 1 are exported, except for the number of patents filed. In the analyses I use the logarithmic transformation of R&D expenditures computed as the natural logarithm of one plus R&D expenditures because many firms invest a zero amount in R&D in at least some of the years. This transformation reduces skewness and sensitivity to outlying values (Wooldridge, 2015).

BvD's Orbis is preferred over alternative databases (e.g. Datastream) because data on SMEs are included. Mainly because reporting requirements vary among countries, where especially data on R&D expenditures within EU countries is in most cases provided on a voluntary basis (Hall & Oriani, 2006), the number of firms in the sample is significantly reduced when only firms with reported numbers are considered. Following Kalemli-Ozcan et al. (2015) who provide a comprehensive study on the BvD database and how to use it, I exclude the companies missing reported data for all years from the sample. As values on R&D expenditures can in fact be zero, even for multiple consecutive years, this exclusion process is already initiated in the variable selection process by exporting the data yearly. Requiring BvD to provide only with data on firms which actually have a 'known value' for that particular year already excludes useless observations. However, exclusion of observations raises the potential issue of selection bias, which is discussed in detail by Hall and Oriani (2006).

Table 1. Operationalization table

This table shows the names of the variables used in the analyses, a short description per variable and how they are measured. R&D expenditures, firm revenues and total assets are measured in thousands of euros, annually. For R&D expenditures and the number of patents, the logarithmic form is used. The number of employees is measured annually. The country variable represents the country of firm incorporation. Industry is measured using BvD major sector and the NACE classification. The post variable indicates whether a firm-level observation post-2007. The NL variable indicates whether a firm is part of the treatment or control group. SMEs, small firms and micro firms are defined according to the definitions provided by the European Commission (2015). The number of patents filed is counted per patent owner per year. For the number of patents filed, the logarithmic form is used. Patent owners in the dataset are incorporated either in Belgium, Germany, France or the Netherlands.

Variable	*Description*	*Measure*
logRDexp	Research & Development expenditures	EUR '000s, annually. Logarithmic transformation calculated as ln(1+RDexp)
Turnover	Firm revenues	EUR '000s, annually
TA	End of year Balance Total	EUR '000s, annually
N_empl	Number of Employees	Annually
country	Country of incorporation	BE, DE, FR, NL
Industry	Main industry of firm's operations	BvD major sector and NACE rev2 core 4 digits
POST	Post-treatment dummy	Equals 1 if year>2007; 0 otherwise
NL	Treatment dummy	Equals 1 if country=="NL"; 0 otherwise
Survivor	Surviving firm	Dummy equals 1 if Turnover is reported for all 8 years
logPatents	The number of patents filed per patent owner	Annually. Logarithmic transformation calculated as ln(Patents)
SME	Small and Medium Enterprise	Dummy equals 1 if N_empl<=250 & (Turnover<=50000 | TA<=43000); 0 otherwise
SMALL	Small firm	Dummy equals 1 if N_empl<=250 & (Turnover<=10000 | TA<=10000); 0 otherwise
MICRO	Micro firm	Dummy equals 1 if N_empl<=10 & (Turnover<=2000 | TA<=2000); 0 otherwise
SB	Science-Based	Dummy variable combing the 2 dgt NACE codes following the Revised Pavitt taxonomy (Bogliancino & Pianta, 2016); 0 otherwise
SS	Specialized Suppliers	Dummy variable combing the 2 dgt NACE codes following the Revised Pavitt taxonomy (Bogliancino & Pianta, 2016); 0 otherwise
SI	Scale and Information intensive	Dummy variable combing the 2 dgt NACE codes following the Revised Pavitt taxonomy (Bogliancino & Pianta, 2016); 0 otherwise
SD	Supplier Dominated	Dummy variable combing the 2 dgt NACE codes following the Revised Pavitt taxonomy (Bogliancino & Pianta, 2016); 0 otherwise
Pharma	Pharma industry	Dummy equals 1 if NACEsector==2110 | NACEsector==2120; 0 otherwise

Generalizing their arguments to this study, I assume the effect of sample selection bias to be limited because (1) a large share of the R&D investing companies actually reports it, and (2) because most R&D is performed by large firms, whom actually report these data. Dutch BvD data are built on LexisNexis Benelux, Graydon and the Dutch Chambers of Commerce. German data are based on Creditreform and Creditreform rating AG, for French data the supplier is Ellisphere and the Belgian data BvD provides stem from the National Bank of Belgium and Coface Services Belgium.

3.3. Descriptive statistics

After merging the annual accounting datasets, the observations containing missing values for turnover, 4313 in total, were dropped. The analysis is further carried out with 18400 observations, including exactly 2300 firms, composed out of 127 Belgian firms, 1330 German firms, 643 French firms and 190 Dutch firms.

In the aggregate sample, the three largest industries in terms of the number of firms are (1) machinery, equipment, furniture & recycling, (2) chemicals, rubber, plastics and non-metallic products and (3) wholesale & retail trade. In the analyses, industries will be held fixed. The dependent and control variables are summarized in the table 2 panel A from the perspective of Dutch vis-à-vis control country firms. According to this table Dutch firms invest more in R&D on average. Simple t-tests provide that, on average across the sample period, Dutch firms have a higher number of employees per firm and generate higher sales.

Except for log R&D, the variables observed for Dutch firms show less variation compared to the control group. Though Dutch firms represent only nine percent of firm observed in this study, their variation in (in)dependent variables is significantly different from the control group. That is, a variance-comparison test shows Dutch firms' volatility is significantly higher in R&D expenditures and significantly lower in total assets and the number of employees. More statistics on Dutch firms based on size are provided in table 2 panel B. These show the coverage of Dutch small firms is not very high. The number of firms within each size group remains relatively stable throughout the sample period.

Table 2 panel C shows the correlations among the dependent variables and controls. All correlations are positive. Note that turnover is a measure used for the classification of SMEs, small and micro firms in the subsample analyses. Higher R&D expenditures are on average associated with higher total assets and a higher number of employees, which corresponds with similar findings in the literature, explained by Hall and Oriani (2006) as follows. Larger firms account for the larger R&D investments. Moreover, larger firms generate higher revenue.

3.4. The Parallel trend assumption

Next, in order to assess internal validity, the parallel trend assumption is discussed. Figure 1 provides a graphical representation showing the mean values in R&D Expenditures over time for the treatment group, relative to the control group.

As can be seen from figure 1 panel A, control firms in the sample increased R&D expenditures on average, from 2005 up to 2011, followed by a decline in 2012. Moreover, in the beginning of the sample period, control firms invested in R&D less than Dutch firms. Contrasting this increasing trend, Dutch firms' R&D investments peaked in 2006 and then fell below control firms' levels in 2008. However, similar to control firms, there was an increase in 2011 followed by a decline in the subsequent year. Bottom line, the graph shows a different pre-treatment trend in R&D levels for the treatment group versus control group, which implies a violation of the assumptions required for a quasi-experimental setting. That is, heterogeneity in R&D levels between the two groups indicates presence of (relevant) systematic differences between them, potentially biasing the findings of this study. The results from further DD analyses are therefore treated with caution. The economic intuition behind this graph could be that Dutch firms experienced a stronger hit from the economic crisis in 2008.

Figure 1 panel B shows how the average level of log R&D expenditures for the industry subsamples based on the Revised Pavitt taxonomy (Bogliacino & Pianta, 2016) moved over time, for the aggregate sample. In correspondence with the category descriptions, the average level of R&D is the highest for the Science Based cluster, followed by the Specialized Suppliers, Scale and Information intensive, Supplier dominated clusters respectively. When scoping on these sectors in The Netherlands versus the control countries (panel C and D), (1) one cannot conclude the pre-2008 levels follow a similar trend, and (2) the graphs do not provide with any reason to believe the 2008 reforms affected R&D behaviour, even in the Science Based cluster.

The parallel trend assumption is tested more formally using t-tests (see table 3). From the table can be seen differences in log R&D expenditures observed in figure 1 are statistically significant in 2005-2007 and 2012. These data underline the necessity to treat post-reform findings from regressions with caution. The results imply that it is unlikely firm, industry or country specific factors do not drive the result in post reform outcome variables. The analysis therefore carries on by eliminating ‘between firm variance’ using the Fixed Effects estimator and by controlling for time varying firm-characteristics. Moreover, because Panier, Pérez-González and Villanueva (2012) establish that from 2002 up to 2009 Belgian, German, French and Dutch countries are strikingly similar in terms of GDP one could argue the use of these countries as control countries is (still) appropriate (as counterargument against the economic intuition described in the paragraph above).

Table 2. Descriptive statistics

Panel A shows the key summary statistics for Dutch firms and the (aggregated) control country firms for the complete sample period. Panel B shows The number of Dutch firms over time, distinguished on size. Larger firms do also include the firms of a smaller size, that is, a Dutch micro firm is also a Dutch small firm, which is also a Dutch SME, which is a Dutch firm. Size definitions are in accordance with the European Commission's (2010) definitions. Panel C shows the correlations among dependent and independent variables. 'logRDexp' denotes the natural logarithm of R&D expenditures, 'TA' is Total Assets, and 'Turnover' is a measure for firm revenues.

Panel A: Dutch firms versus the average control firm

Control countries

	N	mean	median	sd	min	max
N empl	11513	9546.969	468	37135.57	1	536350
TA	13025	2910000	104224	1.46e+07	0	3.10e+08
logRDexp	13023	3.538	0	4.623	0	15.747
Turnover	12934	2080000	86093.5	9330000	-156082	1.99e+08

NL

	N	mean	median	sd	min	max
N empl	947	12391.86	1889	30450.87	1	327680
TA	1062	3260000	409021	9000000	0	9.21e+07
logRDexp	1062	3.681	0	4.922	0	14.964
Turnover	1041	2850000	412003	7090000	-5748	5.67e+07

Panel B: The number of Dutch firms over time, separated based on size

	Total	Dutch	Dutch SME	Dutch Small	Dutch Micro
2005	1501	148	19	4	1
2006	1631	141	16	2	1
2007	1713	138	12	4	2
2008	1735	119	14	4	1
2009	1755	118	16	3	1
2010	1859	126	16	3	1
2011	1918	131	17	3	2
2012	1942	141	19	4	2

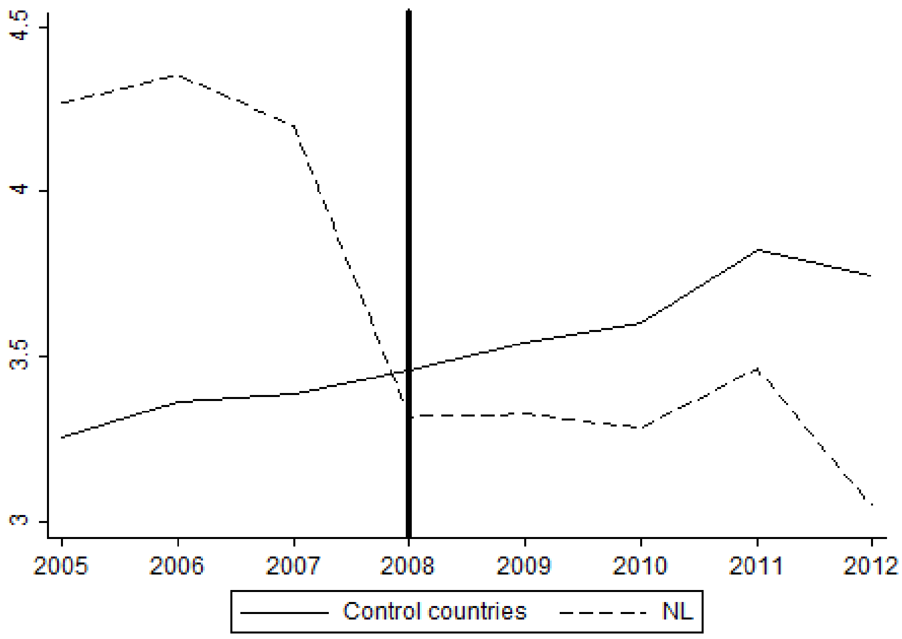
Panel C: Correlation matrix

Variables	logRDexp	TA	N_empl	Turnover
logRDexp	1.000			
TA	0.256	1.000		
N_empl	0.207	0.702	1.000	
Turnover	0.273	0.866	0.796	1.000

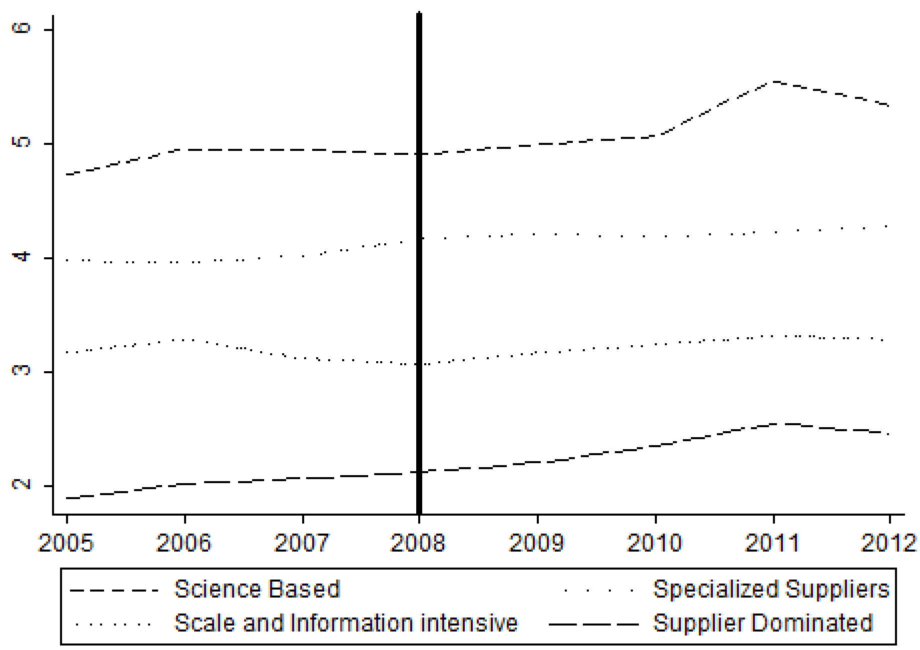
Figure 1. Time trend in log R&D expenditures for Dutch firms vis-à-vis control country firms

These graphs show the average level of the logarithm of R&D expenditures (y-axis) throughout the sample period, for Dutch versus control country firms (panel A), for industry subsamples (panel B) for Dutch industry subsamples (panel C) and control country firm subsamples (panel D). The reference line where year (x-axis) equals 2008 indicates the cut-off point between the pre- and post-treatment period.

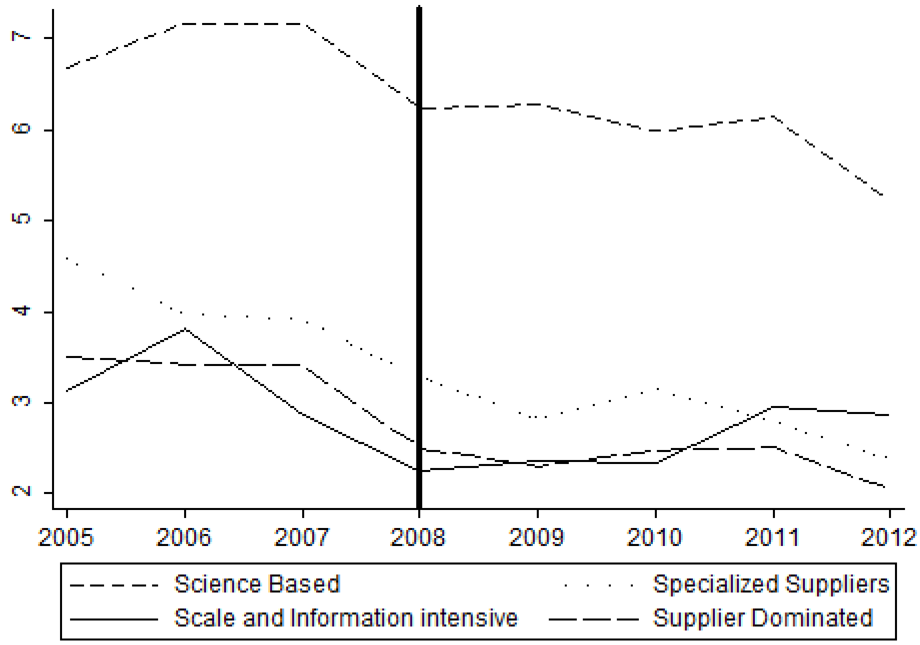
Panel A: Time trend in log R&D expenditures for Dutch firms vis-à-vis control country firms



Panel B: Time trend in log R&D expenditures for industry subsamples



Panel C: Time trend in log R&D expenditures for industry subsamples for Dutch firms



Panel D: Time trend in log R&D expenditures for industry subsamples for Control country firms

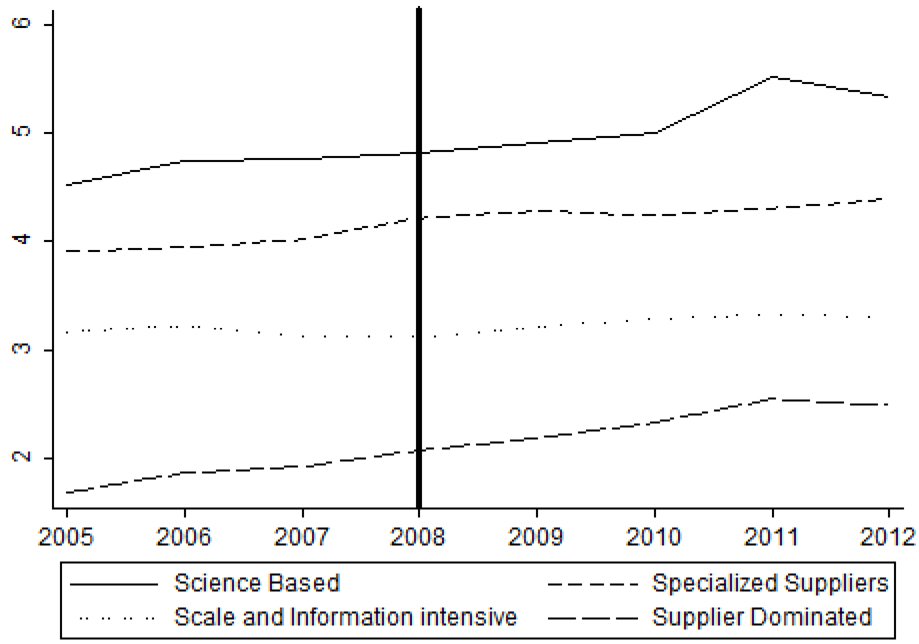


Table 3. Mean investments in R&D over time comparing Dutch with control-group firms

The table below shows the annual differences in means for the Dutch firms vis-à-vis control country firms.

Independent Variable: log Research & Development expenditures				
variable	*Control countries*	*NL*	*Difference*	*T-value*
2005	3.2587	4.2686	-1.0100**	-2.5229
2006	3.3648	4.3525	-0.9877**	-2.4253
2007	3.3880	4.1979	-0.8100**	-1.9669
2008	3.4598	3.3196	0.1402	0.3175
2009	3.5413	3.3275	0.2137	0.4831
2010	3.6006	3.2845	0.3160	1.1568
2011	3.8225	3.4641	0.3584	0.8495
2012	3.7491	3.0471	0.7020*	1.7247
PRE	3.3406	4.2735	-0.9329***	-3.9787
POST	3.6398	3.2834	0.3564*	1.9148

*** p<0.01, ** p<0.05, * p<0.1

4. Results

This section is structured as follows. The first part of this section is dedicated to patent data analyses. The second part is dedicated to the accounting data and first focusses on the complete sample and finalizes with subsample analyses.

The first step in order to evaluate the Dutch 2008 patent law reform's effect is to investigate whether Dutch firms changed their patenting behaviour vis-à-vis Belgian, German and French firms in terms of the number of patents filed. As already mentioned in the data description there is no merge established between the accounting and patent data. For this reason, the unit of analysis in the patent data regressions is the patent owner (instead of the firm). Though this measure is less direct it is still interesting to see whether Dutch patent owners are more or less likely to file patents after the law reforms.

Table 4 presents the first results. Only controlling for country fixed effects, model (1) shows patent owners collectively filed fewer patents after the reform. Moreover, according to model (1), a patent owner filed 6.7 percent fewer patents, on average[2]. Moreover, Dutch patent owners filed fewer patents across the entire eight years of the sample period (24.0 percent fewer patents on average). Dutch patent owners did not file fewer or more patents than the control group after the reform. Controlling for time fixed effects in model (2) does not change the economic and statistical significance substantively. Model (3) provides results for Dutch patent owners on an annual basis and shows in 2009 Dutch patent owners filed on average 8.6 percent more patents

[2] Calculated as $\%\Delta\text{number of patents} = 100 * (e^{\beta_{POST}} - 1)$

than control country patent owners relative to 2005. In 2011 and 2012 Dutch patent owners filed fewer patents (9.7 and 15.8 percent respectively) than the control group relative to 2005.

These results do however not imply the Dutch 2008 patent law reforms had not effect. In fact, because (1) the economic value of patents is highly skewed and (2) only a small percentage of patents is really valuable (Scherer & Harhoff, 2000), a simple increase or decrease in the number of patents filed is unlikely to fully capture the potential effect of the law reforms. It could for example be the case that the reforms allow firms to file higher or lower quality patents than they filed before. Assessing the treatment effect reflected in R&D expenditures addresses this shortcoming in a simple patent count measure. For this reason, the remaining of this section is dedicated to the accounting data. More specifically, I show the effect of the 2008 Dutch patent law reforms (log) R&D expenditures in a pre- and post-period, the course of the effect over time on annual basis and finally I repeat these analysis for subsamples based on firm size.

Table 5 presents the results for the complete sample. The key variable of interest is the 'POST*NL' interaction, which gives the DD interpretation. This variable is included in model (1) and model (2). The table shows in model (1) and (2) with the coefficient on the post-reform variable, there is not enough evidence to conclude the linear relationship between the reforms and Dutch R&D investments in this period is significant, given these data. The DD estimation on the data only implies the aggregate sample increased R&D investments after the patent law reforms. When adding the time-variant controls in model (2), the magnitude of the coefficient on 'POST' increases, that is, in model (1), an R&D investment after the reforms is associated with 60% higher R&D investments[3], whereas in model (2) this POST effect increases to 64%. However, an F-test for joint usefulness of the coefficients on the control variables does not indicate the controls are jointly useful in the model.

Furthermore, one can see from table 5 the effect of total assets and the number of employees do not explain any within-variation in firm R&D investments economically speaking. Though the coefficient of the number of employees is statistically significant at the five percent level, the magnitude of coefficient is economically negligible. A similar result is found in model (3) when modelling the law reform effect on annual basis controlling for year fixed effects. Though the analyses in table 5 do net provide with statistical 'evidence' the patent law reforms affected R&D investments, this does not logically provide evidence for absence of a law reform effect. For instance, an effect could be 'hidden' within a subgroup of Dutch firms.

The logic behind the statement above can be explained as follows. Suppose 90% of the Unit States constituents votes for a black president, it can still very well be the case that there is one or there are even several states

[3] Calculated as %ΔR&D expenditures $= 100 * (e^{\beta_{POST}} - 1)$

voting against any coloured president. In order to mitigate this potential statistical generalization bias, this study continues analysing the results focussing on subsamples.

Table 4, model (3) shows the treatment effect over time. This is done to capture potential lagged effects of patents on innovation. Though Hall, Mairesse and Mohnen, (2010) and Ernst, (2001) argue this lag can sum up to 2 – 4 years, this study provides no evidence of delayed contemporaneous impact of patents on R&D investments. Specific lagged effects are discussed later in this chapter.

Table 4. DD estimation on patent data

This table shows the DD estimation in model (1) and model (2) and the treatment effect over time in model (3), estimated with patent owner-fixed effects. Dependent variable is 'logPatents' which indicates the logarithmic form of the annual number of patents filed per patent owner. 'POST' indicates whether the observation is dating from 2008-2012 or before. 'NL' indicates whether the observation is Dutch. Non-Dutch observations are Belgian, German and French. Year fixed effects are included. As countries vary within patent owner also country fixed effects are included. Robust standard errors are clustered on the patent owner level.

	(1)	(2)	(3)
VARIABLES	logPatents	logPatents	logPatents
POST	-0.0694***	-0.112***	
	(0.00599)	(0.0106)	
NL	-0.274**	-0.278**	-0.274**
	(0.128)	(0.128)	(0.130)
POST*NL	0.0358	0.0307	
	(0.0233)	(0.0232)	
2006*NL			-0.0214
			(0.0251)
2007*NL			0.000133
			(0.0308)
2008*NL			0.0443
			(0.0324)
2009*NL			0.0823**
			(0.0343)
2010*NL			0.0450
			(0.0373)
2011*NL			-0.102**
			(0.0433)
2012*NL			-0.172***
			(0.0558)
Constant	0.668***	0.704***	0.707***
	(0.0910)	(0.0911)	(0.0918)
Year FE	NO	YES	YES
Country FE	YES	YES	YES
Observations	155,133	155,133	155,133
R-squared	0.004	0.005	0.005
Number of patent owners	91,947	91,947	91,947

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

In order to get a more detailed view of 'the Dutch patent law effect', the analysis focuses on heterogeneity within firm size. As the patent law reforms are expected to have different effects within different firm size groups difference-in-differences estimations are now performed on large firms and SMEs. Within SMEs I further distinguish between small and micro firms. The subsample analysis allows to model (time-invariant) firm size, which is not possible within the previous estimated firm-fixed effects models. However, the price paid for this method is the loss of observations per regression.

The results are presented in table 6. Focussing on the coefficient on 'POST' in all models, the data do not indicate the positive association between higher R&D expenses after the reform period vis-à-vis prior to the reforms is different for smaller firm sizes. That is, the same (positive) direction and significance is maintained for smaller firms, with an exception for micro firms. However, when remembering the small representation of micro firms within the sample, high significance is not to be expected. In model (3), the DD coefficient is significant at the five percent level. However, none of the individual years after the reform reflects this effect. The subsample analysis does therefore not provide reason to suggest the effect of patents on R&D is subject to heterogeneity based on firm size.

Next to size heterogeneity, the data is further examined on the industry cluster level. One might expect that, if the 2008 patent law reforms had an effect, this effect would be different for industries relying on patents and R&D on a higher or lower level. Table 7 summarizes the results. As can be seen, in the Science Based cluster (model 1), R&D levels are significantly lower than before. In terms of economic magnitude, the Dutch R&D level within a Science Based firm post reforms would be 205 percent lower than before. However, the least R&D reliant cluster, Supplier Dominated, shows an almost similar negative significant result. Observing this result does not provide reason to believe the Revised Pavitt taxonomy is a relevant factor to explain the patent law effect.

Though, as previously argued, the parallel trend assumption in this study is not satisfied, for the sake of completeness of the analysis the data is also tested on a lagged or delayed effect of the policy changes on R&D expenditures. The results of this analysis where the focus is shifted from (delayed) contemporaneous effects to lagged effects (that is, the models are run in a way as if the policy change was enacted one, two, three and four years later than in reality) can be found in table 8. Coherently with the plotted effects in figure 1, the data show a stronger negative effect when the lag is increased. That is, the difference in R&D investments between Dutch vis-à-vis control group firms increases after 2007. Because of the parallel trend assumption, I interpret this effect as a non-controlled for stronger negative economic crisis effect impacting Dutch firms.

A final subsample analysis focuses on pharmaceutical firms. Because there seems to be some consensus in the literature the patent system is particularly beneficial to pharmaceutical firms (Macdonald, 2004) this study does not only consider firm size but also this particular industry in the subsample analyses. Appendix 1 shows the DD estimations on the pharmaceutical industry subsample. Model (3) reveals Pharmaceutical firms spent more on R&D after the reforms but Dutch firms spent less.

Following guidelines on establishing internal validity when using a DD method, I ran two addition tests. First, in order to make sure control variables are unaffected by the treatment, I replace the dependent variables with controls. The results are shown in appendix 2. As can be seen from both models in the table, the claim control variables (total assets and the number of employees) are unaffected by the treatment cannot be rejected based on the data. Finally, I tested for potential survivorship bias. Regressions with the subsample of survivors generated similar results which makes it unlikely to assume survivorship bias drove the results. Second, I ran all analyses defining 'POST' as 2009-2012 instead of the 2008-2012 period. This provided with similar but slightly less significant results.

Table 5. DD estimations on outcome variables

The table below shows accounting data regressions with firm-fixed effects for the complete sample. Dependent variable is 'logRDexp', the natural logarithm of R&D expenditures. 'POST' indicates whether the observation is pre or post 2007. 'POST*NL' indicates whether the post observation is also a Dutch firm. 'TA' is total assets and indicates the end of year total assets per firm. 'N_empl' is the number of employees per firm, measured per annum. Model (3) include time fixed effects. Robust standard errors are clustered on the industry level.

VARIABLES	(1) logRDexp	(2) logRDexp	(3) logRDexp
POST	0.470***	0.497***	
	(0.114)	(0.102)	
POST*NL	-0.251	-0.211	
	(0.196)	(0.223)	
2006*NL			-0.0428
			(0.149)
2007*NL			0.325
			(0.237)
2008*NL			0.158
			(0.244)
2009*NL			0.122
			(0.330)
2010*NL			-0.120
			(0.271)
2011*NL			-0.246
			(0.353)
2012*NL			-0.536
			(0.421)
TA		8.02e-09	7.15e-09
		(4.85e-09)	(4.52e-09)
N_empl		5.33e-06*	4.66e-06*
		(2.56e-06)	(2.39e-06)
Constant	3.259***	3.517***	3.336***
	(0.0724)	(0.0966)	(0.122)
Year FE	NO	NO	YES
Observations	14,053	12,432	12,432
R-squared	0.027	0.032	0.050
Number of firms	2,289	2,104	2,104

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

Table 6. Difference-in-Differences estimations on R&D expenditures for subsamples

The table below shows accounting data regressions with firm-fixed effects for samples. Definitions of 'LARGE', 'SMALL' and 'MICRO' firms are in accordance with the European Commission's (2010) definitions. Dependent variable is 'logRDexp, the natural logarithm of R&D expenditures. 'POST' indicates whether an observation is post 2007. 'POST*NL' indicates whether the post observation is also a Dutch firm. 'TA' is Total Assets and indicates the end of year total assets per firm. 'N_empl' is the number of employees per firm, measured per annum. Robust standard errors are clustered on the industry level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	logRDexp	logRDexp	logRDexp	logRDexp	logRDexp	logRDexp	logRDexp	logRDexp
POST	0.558***	0.212**	0.110*	-0.0498				
	(0.0818)	(0.0936)	(0.0535)	(0.0576)				
POST*NL	-0.227	0.0970	-0.0992	0.0149				
	(0.234)	(0.289)	(0.170)	(0.0624)				
2006*NL					-0.0510	-0.162***	-0.142	0.231
					(0.201)	(0.0562)	(0.343)	(0.282)
2007*NL					0.289	0.200	-0.0291	0.208
					(0.292)	(0.175)	(0.219)	(0.327)
2008*NL					0.0681	0.392	0.0696	0.204
					(0.308)	(0.268)	(0.325)	(0.311)
2009*NL					0.0517	0.749	-0.181	0.156
					(0.408)	(0.458)	(0.300)	(0.276)
2010*NL					-0.0974	-0.0761	-0.291	0.0967
					(0.306)	(0.343)	(0.235)	(0.265)
2011*NL					-0.297	0.0448	-0.214	0.190
					(0.411)	(0.710)	(0.176)	(0.290)
2012*NL					-0.487	-0.523	-0.239	0.283
					(0.425)	(0.630)	(0.246)	(0.350)
TA	7.61e-09	1.99e-07	2.44e-07	4.79e-07	6.61e-09	1.49e-07	3.21e-07	9.35e-07
	(4.80e-09)	(4.23e-07)	(1.97e-07)	(6.74e-07)	(4.55e-09)	(4.21e-07)	(2.56e-07)	(8.88e-07)
N_empl	4.89e-06*	0.00729***	0.0219***	0.000598	4.15e-06*	0.00725***	0.0241***	0.000110
	(2.49e-06)	(0.00139)	(0.00503)	(0.0129)	(2.34e-06)	(0.00143)	(0.00553)	(0.0135)
Constant	4.303***	1.292***	0.627***	0.236**	4.087***	1.282***	0.638***	0.454
	(0.0988)	(0.187)	(0.106)	(0.0932)	(0.105)	(0.238)	(0.105)	(0.307)
	LARGE	SME	SMALL	MICRO	LARGE	SME	SMALL	MICRO
Year FE	NO	NO	NO	NO	YES	YES	YES	YES
Observations	8,541	3,891	1,137	228	8,541	3,891	1,137	228
R-squared	0.035	0.044	0.026	0.009	0.054	0.063	0.044	0.085
Number of firms	1,468	903	383	106	1,468	903	383	106

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

Table 7. Industry subsample analysis

The table below shows the standard DD estimations using control variables for industry subsamples, based on Pavitt's taxonomy, revised for NACE rev.2. Dependent variable is the logarithm of R&D expenditures. "SB" represents the Science-Based subsample, "SS" represents the Specialized Suppliers subsample, "SI" represents the Scale and Information intensive subsample and "SD" represents the Supplier-Dominated subsample. 'POST' indicates whether an observation is post 2007. 'POST*NL' indicates whether the post observation is also a Dutch firm. 'Total Assets' indicates the end of year total assets per firm. N_empl' is the number of employees per firm. Robust standard errors are clustered on the industry level.

VARIABLES	(1) logRDexp	(2) logRDexp	(3) logRDexp	(4) logRDexp	(5) logRDexp	(6) logRDexp	(7) logRDexp	(8) logRDexp
POST	0.666***	0.397	0.440**	0.527***				
	(0.0766)	(0.277)	(0.181)	(0.139)				
POST*NL	-1.115*	0.293*	0.331	-0.746**				
	(0.426)	(0.0398)	(0.727)	(0.255)				
2006*NL					0.115	-0.342	0.0730	-0.289**
					(0.179)	(0.136)	(0.454)	(0.103)
2007*NL					0.487	0.346	-0.241	0.115
					(0.283)	(0.269)	(0.520)	(0.396)
2008*NL					-0.172	0.420	0.485	-0.500***
					(0.155)	(0.259)	(1.035)	(0.139)
2009*NL					-0.374	0.403	0.129	-0.582***
					(0.230)	(0.224)	(0.997)	(0.136)
2010*NL					-0.960	0.565**	0.190	-0.699***
					(0.487)	(0.0418)	(1.066)	(0.178)
2011*NL					-1.395	0.0867	0.412	-0.883***
					(0.599)	(0.194)	(1.022)	(0.159)
2012*NL					-1.704	-0.0217	0.0799	-1.401**
					(0.966)	(0.207)	(1.130)	(0.546)
TA	8.29e-10	-1.34e-08	7.84e-09	3.45e-09	-1.39e-08	-3.21e-08	6.81e-09	3.64e-09*
	(3.70e-08)	(2.02e-08)	(6.85e-09)	(2.36e-09)	(4.32e-08)	(2.96e-08)	(6.64e-09)	(1.84e-09)
N_empl	1.46e-05	4.18e-06	1.90e-05***	1.06e-06	8.70e-06	3.76e-06	1.90e-05***	7.83e-07
	(1.03e-05)	(3.42e-06)	(2.94e-06)	(1.96e-06)	(1.31e-05)	(3.72e-06)	(2.88e-06)	(1.69e-06)
Constant	4.772***	4.274**	3.363***	2.039***	4.612***	4.141**	3.147***	1.888***
	(0.147)	(0.174)	(0.103)	(0.0856)	(0.143)	(0.253)	(0.172)	(0.104)
	SB	SS	SI	SD	SB	SS	SI	SD
Year FE	NO	NO	NO	NO	YES	YES	YES	YES
Observations	3,436	2,774	2,269	2,723	3,436	2,774	2,269	2,723
R-squared	0.037	0.028	0.052	0.033	0.069	0.048	0.065	0.048
Number of firms	564	509	395	434	564	509	395	434

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

Table 8. Lagged DD estimations on outcome variables

The table below shows the DD estimation in a similar fashion as in table 5, model (2). However, here the dependent variables are lagged one, two, three and four years in model (1), model (2), model (3) and model (4) respectively. 'POST_L1' indicates whether the observation is pre or post 2008. 'POST_L2' indicates whether the observation is pre or post 2009. 'POST_L3' indicates whether the observation is pre or post 2010. 'POST_L4' indicates whether the observation is pre or post 2011. The POST – NL interactions indicate whether the lagged observation is also a Dutch firm or otherwise. Robust standard errors are clustered on the industry level.

VARIABLES	(1) logRDexp	(2) logRDexp	(3) logRDexp	(4) logRDexp
POST_L1	0.886***			
	(0.154)			
POST_L1*NL	-0.313			
	(0.216)			
POST_L2		0.893***		
		(0.155)		
POST_L2*NL		-0.418*		
		(0.201)		
POST_L3			0.896***	
			(0.153)	
POST_L3*NL			-0.458**	
			(0.215)	
POST_L4				0.902***
				(0.156)
POST_L4*NL				-0.542**
				(0.234)
TA	7.25e-09	7.25e-09	7.22e-09	7.18e-09
	(4.51e-09)	(4.51e-09)	(4.52e-09)	(4.54e-09)
N_empl	4.48e-06*	4.52e-06*	4.52e-06*	4.56e-06*
	(2.44e-06)	(2.43e-06)	(2.43e-06)	(2.41e-06)
Constant	3.335***	3.335***	3.335***	3.335***
	(0.124)	(0.124)	(0.124)	(0.123)
Year FE	YES	YES	YES	YES
Observations	12,432	12,432	12,432	12,432
R-squared	0.048	0.049	0.049	0.049
Number of firms	2,104	2,104	2,104	2,104

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

5. Conclusion

This section concludes on the results by returning to the main empirical question brought forward in this study. To what extent did the 2008 Dutch patent law reforms affect Dutch R&D investments? The 2008 Dutch patent law reforms aimed to increase legal certainty with the abolishment of the six-year patent forcing all new patent applications to follow the twenty-year patent application procedure which requires the application to meet standards regarding novelty, non-obviousness and usefulness. Moreover the NPO gained more power in the patent nullification process which was expected to generate higher quality advisory reports from the NPO which increases legal certainty. Next to this, the reforms aimed to decrease translation costs by allowing patent applications to be largely written in Dutch. Third, the reforms aimed to improve patent awareness by providing more incentive to patent owners to reconsider whether to maintain or surrender their patents. This study is designed to assess the effect of these law reforms on Dutch innovation by applying a DD method.

Focusing on the EPO patent data, the results show Belgian, German, French and Dutch patent owners collectively filed fewer patents after the law reforms. Though the law reforms might imply differently, Dutch patent owners did not file significantly more or fewer patents than their control countries. More specifically, the data show Dutch patent owners filed fewer patents before and after the reforms. Based on the literature (Ernst, 2001) the absence of a changing number of patents within the Dutch patent owners does not per se imply the patent law reforms had no effect. This has several reasons. First, the value of patents is highly skewed and only a small percentage of patents is really valuable (Scherer & Haroff, 2010). Secondly, not all innovations which create value are patented (Ernst, 2001) and patents do not generate the same value across industries (Macdonald, 2004).

The accounting data allow to assess the effect of the Dutch 2008 patent law reforms on firm innovation. The data show all firms performed lower after the reforms than before. Based on the analyses there is no reason to believe Dutch firms suffered or befitted from the reforms on average. Because (1) the parallel trend assumption is not satisfied and (2) the post-treatment effects are statistically insignificant, I conclude the ‘Dutch patent law effect’ on the average Dutch firm is limited.

Generalizing this conclusion directly to subsamples (without explicitly testing for it) would be a fallacy. Because the Netherlands Enterprise Agency (2008) clearly indicates different effects are expected for large firms than for SMEs I continue my analysis focusing on subsamples based on size. Formally testing for differences using the same DD estimations, I show within Dutch large firms similar results are obtained as in the complete sample. The patent law changes did not motivate Dutch large firms to spend a higher or lower amount on R&D. The subsample analysis provides no evidence for a patent law effect among small(er) firms.

Another relevant source of firm heterogeneity is considered to be firm industry. More specifically, in industry cluster, which is based on the way firms develop and use technologies. For this purpose, the Revised Pavitt taxonomy is used. Similar to aggregate sample results, pre-reform trends differ, which imposes strong restrictions on the ability to make strong statements on the regression results. The restrictions aside, the regression result remain ambiguous, that is, the most R&D intensive and patent relying cluster, the Science Based cluster, shows a significant negative DD effect. However the least R&D and/or patent reliant cluster shows a similar result. Summing up, I conclude, based on my results, there is little ground to argue the 2008 reforms affected Dutch R&D investments.

A final subsample analysis is conducted on the pharmaceutical industry. Because, among others, Ernst (2001) and Macdonald (2004) argue the pharmaceutical is strongly reliant on the patent system, this study devotes attention particular to this industry. Clustering robust standard errors on the firms level, a DD estimation is conducted. The data show again only weak evidence of a patent law effect. Dutch pharmaceutical firms spent less on R&D after the reforms. Combining the insights from the patent data and accounting data analyses, I conclude based on the data it is very unlikely the 2008 Dutch patent law reforms significantly affected firm innovation.

An important note to this study is that the absence of evidence should never be confused with the evidence of absence. Where one might think the absence of significant results implies the Dutch patent law reforms had no effect on R&D expenditures, it only shows a study which fails to come up with ‘evidence’ to believe there was an effect. The data in this study do in no means provide with a complete evidence of absence. There still might an impact, the results only show study did not uncover any.

6. Discussion

First of all, as already mentioned in the methodology section, a match between patent data and accounting data would expand the possibilities of the analysis. A matched dataset allows to examine the effect of the Dutch patent law reforms on the number of patents filed and preferably a quality adjusted measure for patents (Ernst, 2001), controlling for time variant firm characteristics. This way the impact of the patent law reforms is addressed more directly.

Though it might not seem too obvious, this study could have provided with a significant amount of statistical significant ‘evidence’ for the patent law effect, by relaxing one single assumption: independence of observations within industries. This allows not to cluster robust standard errors on the industry level. But as Betrand, Duflo and Mallainathan (2004) show, especially in DD estimations, using data over multiple years can lead to underestimation of robust standard errors. Though Betrand, Duflo and Mallainathan (2004) point out the key problem of the robust standard errors lies in autocorrelation, this study maintains a conservative approach containing many clusters mainly due to the fact firms’ patenting behaviour within industries is unlikely to be independent. The subsample analysis on the pharmaceutical industry provides some evidence this is actually the case.

One could argue better results are obtained when testing for the patent law effect using specific hypotheses for different reform implications. For example, including patent quality measures in the patent data could be used to test whether increased uncertainty triggers firms to file more impactful patents in the Netherlands. If the patent data includes European patents it allows for testing whether the law reforms shift Dutch patent owners to file their patents more or less often on the European level. A measure for perceived legal certainty could also expose an impact of the law reforms more directly.

The coverage of SMEs in the sample is rather low. Because this study focused besides regular firm performance measures also on R&D (which is not reported very often by small firms) the sample contains mainly large firms. In further research subsample analyses could exclude R&D and require firms only to report firm performance variables. This would significantly increase the coverage of small firms in the sample. Specifically related to SMEs, further research should be conducted including firm data on venture capital, entrepreneurial spirit and education of chief executives. According to Macdonald (2004) these variables are stronger predictors of innovation (than patents do). This inclusion allows to observe whether non-patented inventions change due to the patent law reforms.

Internal validity of this study could have been increased by, similar to Panier, Pérez-González and Villanueva (2012) collect firm-level data from additional control countries and replicate the DD estimations using a nearest neighbour matching procedure, which matches firms based on similar pre-reform characteristics. This method contributes to internal validity because it makes it less likely the observable time-varying firm characteristics explain the result. In this case it makes sense to include more firm specific controls to increase the quality of the matches. Studying the patent law effect using this method could be an avenue for future research.

Furthermore, several alternative explanations are ruled out. First, reverse causality is accounted for. That is, control variables are not driven by the patent law reforms. Second, correcting the log of R&D expenditures for the many firms investing (near) 0 in R&D did not significantly change the results.

The results do also allow to make some inferences regarding the theory. Artz et al., (2010) find a positive relationship between patents and R&D investments. Though they also expected to find a positive relationship between patents and Return on Assets and sales growth, they find a negative one. They explain this by arguing this finding could be due to the strategic use of filing patents, labelled 'strategic patenting'. This study contributes to this line of thinking in showing the absence of an increase or decrease in firm performance is not accompanied by a change in R&D expenditures. In other words, this study shows by also investigating R&D expenditures that though the law reforms did not affect firm performance, they also left R&D expenditures unaffected. If strategic patenting were present one would expect at least to see R&D expenditures to change significantly. The contribution is that the Dutch patent law effect reveals a case where there is no reason to believe strategic patenting dominates firms' patenting behaviour. However, further research should be conducted specifically addressing this issue.

Finally, Relating to the pharmaceutical subsample, the data show after the law reforms Dutch pharmaceutical companies decreased their R&D investments significantly more. Though the parallel trend assumption is not satisfied, this result could indicate after the reforms, the Dutch legal patent climate became less interesting for the pharmaceutical industry. However, in order to make inferences on strategic patenting by Dutch pharmaceutical companies based on the lower investments in R&D, further research should be conducted.

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Appendix 1: Pharmaceutical industry subsample

VARIABLES	(1) logRDexp
POST	0.764***
	(0.270)
POST*NL	-0.661*
	(0.354)
TA	-4.56e-08**
	(2.18e-08)
N_empl	4.72e-05*
	(2.69e-05)
Constant	7.165***
	(0.192)
	PHARMA
Observations	463
R-squared	0.055
Number of firms	74

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

*Note that robust standard errors are clustered at the firm level.

Appendix 2: Reverse causality

VARIABLES	(1) TA	(2) N_empl
POST	350,311*	567.1**
	(187,785)	(228.4)
POST*NL	824,361	-2,177
	(648,223)	(1,792)
N_empl	333.8**	
	(142.2)	
TA		0.000693***
		(0.000158)
Constant	-292,602	7,269***
	(1.356e+06)	(467.6)
Observations	12,433	12,433
R-squared	0.235	0.235
Number of firms	2,105	2,105

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

Appendix 3: Extended summary

Theoretical part

The main question of this study assumes patents should affect innovation. This assumption is based on the idea that the provision of intellectual property rights to companies spurs innovation. Before moving on with the empirical part we first deal with some definition and then discuss why it makes sense to use an innovation incentive system, under what conditions the use of patents is justified, what are the shortcomings of the patent system, and under what assumptions are alternatives more viable? Furthermore, the discussion focuses on the role of patent in innovation and in firm performance. For this purpose, potential heterogeneity within firm size and across industries are explored.

A patent is the exclusive right to market an invention for a fixed period of time. Patents are a form of Intellectual Property (IP), which includes copyrights and other forms of legal as well. Another definition of a patent is provided by Lehman (2003, p.2): *"patents are exclusive property rights in intangible creations of the human mind"*. Lehman (2003) further defines the patent by noting that *"patents exist only as provided in the laws of sovereign states and can be enforced only to the extent that application has been made and a patent granted covering the territory of an individual state"*. Furthermore, patents are characterised by a finite duration, with a general global average of about 20 years. Additionally, patents need to meet certain requirements of newness, usefulness and non-obviousness, which is discussed in more detail in the empirical part. The procedure where the patent authority checks whether these requirements are met is called examination for 'prior art'.

An innovation incentive system obtains its right to exist from the fact that firms need compensation for being the first to invest in an invention. That is, a competitor in the same industry as this inventor familiar with the product or service will be able to imitate the invention and consequently commercialize it at a lower total cost. It therefore makes sense to compensate firms in some way for investing in innovation.

In the literate two main alternatives to Intellectual Property are brought forward (Gaillini and Scotchmer, 2002). Both alternatives make use of a public sponsor, governing the development outcomes. First, there is the price system, which includes a reward issued by a public sponsor, upon completion of an invention. This system works best when there is only one party capable of developing the invention. The price amount is to be a priori determined and issued if and only if the invention is developed, where the social value criterium is met. Another alternative to IP is the procurement system, where the development project is allocated to the firm bidding the highest social value in an auction. Here, the costs are reimbursed by the public sponsor before development. To prevent 'take-the-money-and-run moral hazard attached to this, the reward can be staged, contingent on certain milestones. This system works best when the public sponsor can accurately ex-ante determine what the social benefits of the invention will be. Now, we consider IP. Allocating a right to commercialize an invention for a specific time to one company can only work best when there are information asymmetries. The information asymmetries arise where firms do not know whether it is wise to invest because they cannot determine the other firms' costs and benefits. If there were no such asymmetries, one of the other two systems would be more attractive. This is because the IP system comes at a cost. Because the IP holder is a monopolist she will price accordingly. This creates a deadweight loss. The social value should therefore compensate for these costs.

Gaillini and Scotchmer (2002) then state that the firm's utility can be aligned with social value by making the reward from the public sponsor to the developer equal social value. I argue that this is not the case, because firms will still be able to make other investment options, or, evaluate the strategic value of the patent and not to innovate. If the latter benefits exceed taking the project, the patent forms an impediment to innovation.

From another point of view, one can argue for a negative relation between patents and innovation as well. Considering settings where innovation is mostly complementary to other innovations, or sequential (it builds on the previous one) innovation even benefits from a lack of IP protection. When there is IP protection, the knowledge competitors observing innovations from a certain company have cannot be implemented, which creates a loss for society. Bessen and Maskin (2009) even argue that a licencing agreement with these competitors would still be less profitable to the inventor than not use the competitors' ideas, due to profit dissipation.

At this point it is useful to make a distinction between innovation, inventions and patents. First, not all inventions are patentable. Sometimes inventions do not meet the criteria to be patented. In order for a patent to be granted it must be (1) novel in a legally defined way, which means in European countries: first-to-file, whereas it means in the US: first-to-invent. Moreover, the patent has to be (2) nonobvious. This means a highly skilled professional in the specific are of the patent would need the patent in order to achieve the same output. And finally, the patent must be (3) useful in a sense that allows for commercialization of the patent (Hall, Jaffe & Trajtenberg, 2005). The point is that inventions which are not patentable can in fact create value.

Second, not all patentable inventions are patented. Whether to file patent or not is a strategic decision (Hall, Jaffe & Trajtenberg, 2005). The strategic consideration can be not to file the patent to maintain discretion regarding the invention. Another strategic consideration is to file the patent first (before other market players do), aiming just to own the patent and potentially delay innovation. The intuition behind this is discussed further ahead in this section. Furthermore it is important to distinguish between inventions and innovation.

Inventions focus on the development of new ideas, whereas innovation relates to the development of commercially viable products or services from creative ideas (Artz et al., 2010).

Third, the economic value of inventions as well as patents vary substantively. That is, only a very small percentage of the distribution of inventions and patents are (1) extremely valuable and (2) actually commercialized up to this full value potential. The reason for this is the distribution of innovation success is highly skewed. Only a small number of innovations is highly valuable. In Taleb's (2007) 'Extremistan', inequalities are such that one single observation can disproportionately impact the aggregate, or the total. Entities within this world are thus characterized by a high degree of unpredictability. I argue the economic value and ability to commercialize them up to their full potential are both variables belonging to 'Extremistan'. This makes investing in patents a risky venture (making a case for strategic patenting). Concluding this argument, because unpatented innovation is more difficult to measure than patented innovation, patented inventions still form the best or most measurable expression of innovation input, but it has its limitations.

When measuring the effects in firm performance of patents, in the literate (e.g. Ernst, 2001) there is usually a lagged effect considered between two to three years. Other empirical results (Artz et al., 2010) show a negative relationship between patents and Return on Assets. These scholars explain their result by the 'strategic patenting' phenomenon. Macdonald (2004) takes this idea even further and makes a case for the patent system mainly serving the pharmaceutical industry instead of serving innovation (to society).

Besides a general discussion of the effect of patents on innovation, this study also considers heterogeneity within firm size or across industries. Whereas large firms have the financial resources to their disposal to employ a strategy of strategic patenting, SMEs face relatively higher costs in acquiring and enforcing patents and therefore, employing such an anti-competitive strategy could be too costly resulting in a different patents-innovation relationship. However, SMEs differ from large firms in a sense that they have shorter lines of communication, relatively informal decision making and more flexibility, which provides them with an advantage in realizing more rapid innovation compared to large firms (Maravelakis et al., 2006). But, when it comes to filing patents, Hogersson (2012) found that the main reasons for entrepreneurial firms not to issue patents are because of financing (e.g. attracting venture capital). Moreover, as the impact and associated financial benefits of patents cannot be a priori determined, SMEs might be reluctant in using property protection when conducting business, making an argument against a positive innovation-through-patents-innovation relationship. For these reasons, I argue the level of uncertainty involving the choice to file a patent as well as to commercialize them is more severe within SMEs than within large firms.

Besides in size, firms treat innovation differently, depending on the industry they operate in. Focussing on exactly this varying role of innovation among industries, considering the Pavitt 1984 taxonomy is relevant. In particular, the Revised Pavitt taxonomy (Bogliaciano & Pianta, 2016), which is adapted to the NACE 2 revision, provides a useful framework to describe the role of innovation on the industry level. The Revised taxonomy classifies NACE sectors as follows; (1) Science-Based (SB), focussing on the industries relying most heavily on R&D, that is, this category includes sectors where innovation is based on science and R&D together with a high propensity to patent. This class includes among others the pharmaceutical industry, electronic industries and telecommunications. The next category is (2) Specialized Suppliers (SS), which denotes the sectors producing machinery and equipment. Importantly, the key source of innovation in this industry cluster are tacit knowledge and design skills, embodied in the labour force. Here, R&D is still relied upon, but in terms of priority to obtain innovation output it is inferior to tacit knowledge. Among others, this category includes real estate activities and legal and accounting activities. In (3) Scale and Information intensive (SI) sectors, firms focus predominantly on scale economies and standardization of the production process. Consequently, innovation is mostly incremental as changing the process comes at a high cost. Typical examples within this category are the automotive industry and financial service activities. The last category entails (4) Suppliers-Dominated (SD) industries, includes the traditional, less innovation reliant sectors. Typical examples are the food and textile industries. They acquire innovation through inputs and machinery from other sectors. Concluding, the industry clusters are ranked ordinally from high R&D intensity and propensity to patent in (1) to less reliant on R&D and characterized by a low propensity to patent (4).

Empirical part

The empirical part is devoted to the following research question. To what extent did the 2008 Dutch patent law reforms have an effect on firm innovation? In the summer of 2008, the Dutch government enacted changes in patent law, aimed to increase legal certainty, reduce translation costs and to improve patent awareness.

Patents provide inventors with intellectual property protection. Though not all innovations are patented, patents still remain a useful way to measure innovation, because (1) they contain highly detailed information about the invention, and (2) they are more measurable then alternatives (Agostini et al., 2015). However, it remains a challenge to disentangle the effect of innovation through patents on innovation because the economic value of patents is highly skewed and only a small percentage of patents is truly valuable (Scherer and Harhoff, 2000). Some studies addressed this issue by applying quality-weighted measures for patents (e.g. Ernst, 2016; Agostini et al., 2015). However, the application of different ways to account for patent quality does still not address the fact the relationship between patents and firm innovation is endogenous.

Several studies addressed this endogeneity issue allowing for a time lag from two up to four years between invention or patent grants and subsequent firm performance (e.g., Ernst, 2001). Though this approach makes reverse causality less likely, endogeneity is still not fully accounted for (Bellemare, Masaki & Pepinski, 2017).

Of particular interest in this patents – innovation relationship are Small and Medium size Enterprises (SMEs). This particular type of firms is considered to be an important innovator in many industries (de Rassenfosse, 2012). Moreover, the literature provides evidence that SMEs increasingly use patents (e.g. Jensen & Webster, 2006). However, due to earlier mentioned uncertainty regarding intangible assets such as patents (Hall & Oriani, 2006), especially SMEs which face more financial resource constraints than large firms are disadvantaged in their ability to acquire and commercialize patents.

To investigate to what extent the 2008 Dutch patent law reforms affected Dutch firms' performance, the empirical strategy builds on a Difference-in-Differences (DD) approach combined with a Fixed Effects estimator, which is designed to address the endogeneity issue relating to the patents-innovation relationship outlined above. Based on the assumption the Dutch Government passed the enacted Patents Act independently of Dutch firms, I compare the difference-in-differences between Dutch firms in a pre- and post-2008 period with a group of control countries composed of Belgium, Germany and France. These countries are geographically close, economically integrated, and share the same currency as Dutch firms. They are therefore assumed to be subject to the same macro-economic shocks as Dutch firms. Yet, these countries did not pass similar patent law reforms right around 2008.

Drawing on patent panel data from the European Patent Office (EPO) for the period of 2005-2012, I show with a DD estimation Dutch patent owners did not file fewer patents after the reforms, but also before. To further identify the effect of the 2008 Dutch patent law reforms, firm level accounting data for the same period are collected from Bureau van Dijk (BvD). Again using a DD estimation, the data show when controlling for time-variant firm characteristics, the reforms did not induce Dutch firms to spend more on R&D. Moreover, I show the parallel trend assumption is unlikely to hold. I then perform subsample analyses to investigate heterogeneity within firm size and across industry clusters, based on the aforementioned Revised Pavitt taxonomy. Then, I test for specific lagged effect for one up to four years. The results close with an additional model dedicated to the pharmaceutical industry.

Further analysis shows there is only weak evidence the amended Patents Act had a different effect on large firms than on SMEs. It is however not unlikely this result is due to a small representation of SMEs within the sample. The industry cluster subsamples generate an ambiguous result. Average R&D levels move in different directions for different industry clusters, at a marginal significance level of five percent. Then, for the sake of completeness, tests are ran using lagged depended variable models. Due to the aforementioned parallel trend assumption violation, I interpret the significant outcomes as a stronger economic crisis effect hitting Dutch firms than control firms. A final subsample analysis of the pharmaceutical industry shows Dutch pharmaceutical firms decreased R&D investments after the patent law reforms. Because the evidence is not statistically robust I argue there is not enough evidence to conclude the 2008 Dutch law reforms significantly affected firm innovation.

The contributions of this study are twofold. First, using a quasi-experimental design, an evaluation of the effect of Dutch patent law reforms on firm innovation is provided. Second, by integrating the reforms in a theoretical context, this study draws additional attention to the unresolved endogeneity issue regarding the relationship between patent filings and innovation.

The Dutch patent law reforms in 2008 changed aimed to (1) increase legal certainty among all parties involved, (2) reduce translation for Dutch and international patent applicants and (3) improve patent awareness among all parties involved (Netherlands Enterprise Agency, 2008). The most important changes of the law regarding these three goals are outlined and interpreted below.

By abolishing the six-year patent, the law reforms aim to increase legal certainty. Before 2008, when applying for patents, applicants could choose to request a 'search of prior art' or apply without such a report at all. If they did not choose for this search report, the patent's term was six years. Moreover, in this case the patent was granted no matter the claimed invention was patentable. After the grant the Dutch courts had to decide on the patent's validity (in case of objections). On the other hand, patent applications based on the 'examination for prior art' had a term of twenty years. In a revision of the Dutch Patents Act, the Dutch government stressed the six-year patent induced unwanted uncertainty for both the patent proprietor and third parties. It is therefore abolished. As a result, after the Dutch patent law reforms, all new Dutch patent applications will follow the twenty-year patent application procedure. After the amended Patent Act, all new patents will require a search report and moreover, a written opinion of the EPO is included examining the relevance of the cited documents.

Additional to the 6-year patent abolishment, The amended Patent Act increases the role of the Netherlands Patent Office in proceedings for patent nullifications to increase legal certainty. Anyone can ask the NPO for an advisory report regarding the validity of a particular patent. The advisory report is made based on a third party's request. The Dutch court then usually concludes in accordance with the advisory report. Before the 2008 reforms, the NPO could only consider patent nullification based on arguments made in the third party's request. The amended Patent Act empowers the NPO to provide also additional arguments for nullification in the advisory report which are not included in the request but can be derived from the search report. This increases the scope of the NPO in compiling advisory reports regarding patent nullifications. According to the Netherlands Enterprise Agency (2008) this will increase quality of the search reports and nullification procedures and therefore increase legal certainty regarding Dutch patents.

The amended Patents Act allows patents to be filed in English (expect for the claims, which still have to be in Dutch). Pre-2008 Dutch patent law required the complete patents to be filed in Dutch. As a reason for this, the amended Patents Act states filing in English is allowed to reduce translation costs for Dutch applicants when filing patents outside the Netherlands. According to the Netherlands Enterprise Agency (2008) this change is beneficial to both Dutch and international applicants filing in the Netherlands. As new Dutch patents can be used more easily abroad when filing international patents, the Dutch patent becomes more attractive. Especially SMEs are expected to benefit from these reduced translation costs. Based on this reform, the Netherlands Enterprise Agency (2008) expects an increase in the number of patents filed by foreign companies in the Netherlands. However, because the acceptance of Dutch patent applications in English is unilateral, Dutch firms might not yet benefit from reduced translation costs when filing internationally but could even be put at a disadvantage. For example, a Dutch firm can file a patent in English in the Netherlands. A French firm can file the same patent in English in the Netherlands. However, the Dutch firm cannot file this patent in France in English. In this case the patent would have to be translated into French. French firms therefore have to advantage that they can choose to file a patent in the Netherlands either in Dutch or in English. Dutch firms filing in France have only one choice. Again, this is expected to mainly affect SMEs (Netherlands Enterprise Agency, 2008).

Another implication of the reforms is that Dutch companies with an insufficient proficiency of the English language trying to avoid infringement of competitors' patents cannot directly read the entire content of the patent. The bearer of the translation costs becomes the Dutch firm instead of the international firm who is released from the translation requirement. According to the Netherlands Enterprise Agency (2008) this change will affect small firms rather than large firms. It is therefore not clear whether Dutch SMEs will either benefit from reduced translation costs because filings outside the Netherlands are allowed to be in English or suffer from the fact descriptions of claims in new patents are allowed to be in English.

The law changes aimed to improve patent awareness include the movement of the first annual fee from the fifth year after the patent filing date to the fourth year after the patent filing date. The annual fees are increase progressively as the patent ages. Shortening the no-fee period by one year provides patent owners with a higher incentive to assess the necessity to maintain their patents. Netherlands Enterprise Agency (2008) states 3 years is sufficient to fully explore the commercial potential of a patent. The amended Patent Act is therefore not expected to negatively affect patent owner's ability to assess the commercial probabilities of a its patents. The annual fees start from a few tens of euros the first year, al increasing to approximately 1.5 thousand euros in the 20^{th} year. Moving the annual fee one year earlier should decrease the number of unused patents held by Dutch firms because holding the same patent for the same time after the law reforms is more expensive than it used to be before the reforms.

To aim of this study is to investigate to what extent the Dutch 2008 patent law reforms had an effect on Dutch R&D investments. Because the relationship between patents and innovation is potentially endogenous, the effect due to the patent law reforms can only be observed when isolating potential confounders. To pursue this goal, I combine two established methods both used in the corporate finance literature to get the optimal result. First of all, I use a Difference-in-Differences (DD) approach. Using an quasi-experimental setting, this method allows to identify cause-and-effect relationships (Roberts & Whited, 2011). The second method entails the addition of the Fixed Effects estimator to the DD estimator, which allows to rule out the effect of (un)observed time invariant effects. Combining these two methods, the effect of potential confounders is mitigated in several ways.

Using the patent law changes in the Netherlands in 2008 as a treatment effect this study aims to mimic the design of a randomized controlled trial as closely as possible. The underlying assumption is the patent law change is exogenous or plausibly unconfounded (i.e., independent of the outcome variables). More specifically, I assume Dutch firms did not collectively influence the Dutch government's decision to enact the patent law changes in 2008.

One way to account for possible differences on the firm level is to control for them. Similar to Agostini et al. (2015) in estimating the effect of patenting on (SME) performance, I control for firm size. The time variant controls for firm size are Total Assets and Number of Employees. The model below presents the DD model as described above. Time variant firm-level controls represent total assets and the number of employees. Additionally, country- industry- and year fixed effects are included.

$$R\&D\ Expenditures = \alpha_i + \beta_1 Post_{it} + \beta_2 NL_i + \beta_3 Post_{it} * NL_i + \beta_4 Total\ Assets_{it} + \beta_5 Number\ of\ Employees_{it} + \beta_6 Country\_dummies_i + \beta_X Year\_dummies_t + \beta_Y Industry\_dummies_i + a_i + u_{it}$$

Where subscript "*i*" indexes firms and "*t*" indexes year. If factors other than the treatment (e.g., the 2008 economic crisis) would have an effect on the outcome variable, this would be reflected in "β_1", the coefficient on the post-treatment period. If Dutch firms in general have different levels of the outcome variable than the control group, this would be reflected in "β_2", the coefficient identifying the treatment group. If the patent law reforms have an effect this is reflected in "β_3". Using this approach, unobserved heterogeneity is eliminated on the country and the post-treatment level. This quasi-experimental method is proven in empirical business research (Roberts & Whited, 2013; Bertrand & Mullainathan, 2003). Note that the error term is split up in a time invariant component "a_i" and a time variant component "u_{it}" distinguishing different types of potential confounders. This distinction is discussed below.

Taking the elimination of potential confounders even further, the unobserved heterogeneity (a_i) is considered not only at the country level but at the firm-level as well. Firms can (and probably they do) differ on individual level, e.g., one firm can be more effective in commercializing innovations than another firm (assuming this ability is constant over time, which could be expressed in a more or less effective CEO serving a company for several years). Or alternatively, firms can differ in their ability to access additional capital required to innovate, which makes it more difficult for some firms to achieve innovation than for others. Both examples will have an effect on the performance of the firm. The FE transformation removes these firm fixed effects from the error term. This allows to relax the assumption that all firm fixed effects are controlled for. This results in the following general model.

$$R\&D\ Expenditures = \beta_1 Post_{it} * NL_i + \beta_2 Total\ Assets_{it} + \beta_X Number\ of\ Employees_{it} + \beta_Y Year\_dummies_t + u_{it}$$

Betrand, Duflo and Mallainathan (2004) already raised the issue that often in DD analyses, standard errors are too low, leading to artificially inflated t-values and very low p-values accordingly. Therefore, robust standard errors are clustered at the industry level. This choice has two reasons. The theoretical argument is that across industries the preference to be patent-active is heterogenous (Ernst, 2001). The technical reason is that though one could argue the countries are the key source of variation in the analysis, the clustered standard errors will only converge to the true standard errors as the number of clusters increase. Country-level clustering provides with only four clusters. Therefore, clustering on the industry level is preferable, as it provides with more clusters.

After merging the annual accounting datasets, the observations containing missing values for turnover, 4313 in total, were dropped. The analysis is further carried out with 18400 observations, including exactly 2300 firms, composed out of 127 Belgian firms, 1330 German firms, 643 French firms and 190 Dutch firms.

The crucial assumption underlying the DD approach to establishing internal validity, is that pre-treatment levels in the outcome variable follow a similar trend. Both using graphical evidence and statistical evidence I identify some issues regarding this assumption. This finding warns to treat the regression results with caution.

Focusing on the EPO patent data, the results show Belgian, German, French and Dutch patent owners collectively filed fewer patents after the law reforms. Though the law reforms might imply differently, Dutch patent owners did not file significantly more or fewer patents than their control countries. More specifically, the data show Dutch patent owners filed fewer patents before and after the reforms. Based on the literature (Ernst, 2001) the absence of a changing number of patents within the Dutch patent owners does not per se imply the patent law reforms had no effect. This has several reasons. First, the value of patents is highly skewed and only a small percentage of patents is really valuable (Scherer & Haroff, 2010). Secondly, not all innovations which create value are patented (Ernst, 2001) and patents do not generate the same value across industries (Macdonald, 2004).

The accounting data allow to assess the effect of the Dutch 2008 patent law reforms on firm innovation. The data show all firms performed lower after the reforms than before. Based on the analyses there is no reason to believe Dutch firms suffered or befitted from the reforms on average. Because (1) the parallel trend assumption is not satisfied and (2) the post-treatment effects are statistically insignificant, I conclude the 'Dutch patent law effect' on the average Dutch firm is limited.

Next, I show within Dutch large firms similar results are obtained as in the complete sample. The patent law changes did not motivate Dutch large firms to spend a higher or lower amount on R&D. The subsample analysis provides no evidence for a patent law effect among small(er) firms.

Another relevant source of firm heterogeneity is considered to be firm industry. More specifically, in industry cluster, which is based on the way firms develop and use technologies. For this purpose, the Revised Pavitt taxonomy is used. Similar to aggregate sample results, pre-reform trends differ, which imposes strong restrictions on the ability to make strong statements on the regression results. The restrictions aside, the regression result remain ambiguous, that is, the most R&D intensive and patent relying cluster, the Science Based cluster, shows a significant negative DD effect. However the least R&D and/or patent reliant cluster shows a similar result. Summing up, I conclude, based on my results, there is little ground to argue the 2008 reforms affected Dutch R&D investments.

A final subsample analysis is conducted on the pharmaceutical industry. Because, among others, Ernst (2001) and Macdonald (2004) argue the pharmaceutical is strongly reliant on the patent system, this study devotes attention particular to this industry. Clustering robust standard errors on the firms level, a DD estimation is conducted. The data show again only weak evidence of a patent law effect. Dutch pharmaceutical firms spent less on R&D after the reforms. Combining the insights from the patent data and accounting data analyses, I conclude based on the data it is very unlikely the 2008 Dutch patent law reforms significantly affected firm innovation.

An important note to this study is that the absence of evidence should never be confused with the evidence of absence. Where one might think the absence of significant results implies the Dutch patent law reforms had no effect on R&D expenditures, it only shows a study which fails to come up with 'evidence' to believe there was an effect. The data in this study do in no means provide with a complete evidence of absence. There still might an impact, the results only show study did not uncover any.

Finally, several alternative explanations are ruled out. First, reverse causality is accounted for. That is, control variables are not driven by the patent law reforms. Second, correcting the log of R&D expenditures for the many firms investing (near) 0 in R&D did not significantly change the results.

This findings of this study contribute to the theory as well, by showing the absence of an increase or decrease in firm performance is not accompanied by a change in R&D expenditures. In other words, this study shows by also investigating R&D expenditures that though the law reforms did not affect firm performance, they also left R&D expenditures unaffected. If strategic patenting were present one would expect at least to see R&D expenditures to change significantly. The contribution is that the Dutch patent law effect reveals a case where there is no reason to believe strategic patenting dominates firms' patenting behaviour. However, further research should be conducted specifically addressing this issue.