FIRM INNOVATION AND RESEARCH & DEVELOPMENT COSTS UNDER IFRS

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ABSTRACT

This paper examines the relationship between research and development (R&D) expenditures under International Financial Reporting Standards (IFRS) and firms' innovation, proxied by future patent counts and patent citations. Accounting for R&D is a major difference between IFRS and generally accepted accounting principles in the United States (US GAAP). The difference is that certain development costs can be treated as assets under IFRS, but all R&D expenditures are expensed under US GAAP. This difference in the accounting treatment is grounded in the conceptual question of whether R&D expenditures provide future benefits, consistent with the definition of an asset, or whether the benefits are so uncertain that they are treated as the consumption of resources, consistent with the definition of an expense. If R&D expenditures provide future benefits, they are expected to be associated with future patents and citations. Capitalized development costs should exhibit a stronger association as they meet the criteria to be assets, expecting to provide future benefits. Expensed R&D can also be associated with patents and patent citations as these expenditures may also lead to patents and patent citations. As expensed R&D relates to expenditures in the research stage or those development costs that do not meet the criteria to be capitalized, the association should be weaker. Therefore, this paper examines the association between R&D expenditures that are expensed and those that are capitalized under IFRS with patents and patent citations as future benefits.

Using a hand-collected sample of high-tech firms in European Union from 2012 to 2018, this paper finds economically and statistically significant different associations between capitalized development costs and expensed R&D and a firms' innovation, as proxied by future patents and patent citations. Using median effects, the association between one million euros investment in firms' capitalized development costs and patent counts (citations) is 200% or more than the association between one million euro's expensed R&D and patent counts (citations).

This paper is one of the first to examine the relationship between R&D capitalization under IFRS and firms' innovation, as measured by future patent counts and patent citations. This paper contributes to the literature on R&D capitalization by identifying the fundamental difference in the association between capitalized development costs and expensed R&D and innovation. Further, this paper contributes to our understanding of the accounting for R&D, and the different treatment between US GAAP and IFRS by finding that capitalized development costs display a different association from expensed R&D.

Keywords: R&D capitalization, capitalized development cost, expensed R&D, IFRS, innovation, patent counts, patent citations

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CHAPTER 1

INTRODUCTION

This paper examines the relationship between firms' innovation and research and development (R&D) accounting under International Financial Reporting Standards (IFRS). Accounting for R&D is a major difference between IFRS and generally accepted accounting principles in the Unites States (US GAAP)[1]. The difference is that certain R&D costs can be treated as an asset under IFRS but all R&D costs are expensed under US GAAP. Prior literature that examines the informativeness of R&D accounting about future performance focuses on testing the relationship between capitalized R&D and firms' financial performance (e.g., stock price returns, return on assets) with mixed findings. The mixed results could be due to the measurement complexity in the R&D investment's prolonged return, the noise in the financial performance measures such as macroeconomics influence, the availability and reliability of R&D data in the mainstream database, and the use of a broad industry sample where R&D could be less important comparing to other intangibles in the prior research. This paper uses a long-term non-financial performance measure specific to firms' innovation to examine R&D investment and outcomes of the R&D spending. Firms' innovation, proxied by patent counts and patent citations, as the direct output of firms' R&D activity, is directly linked with firms' R&D costs (the input of the R&D activity). Compared to financial performance measures, innovation as a direct product of firms' R&D activity is less noisy and

[1] IFRS mandates that development costs be capitalized if certain criteria are met (IAS38).
US GAAP requires immediate expensing of R&D costs within the scope of 'ASC 730 Financial Statement R&D'. Motion picture films, website development, cloud computing costs and software development costs are the only exceptions that might qualify for R&D capitalization Under US GAAP.

expected to show a stronger association with firms' R&D spending. Specifically, using hand-collected R&D samples from high-tech firms, I examine whether R&D expenditures under IFRS, both expensed and capitalized, are associated with a firm's future innovation proxied by patent counts and patent citations. Furthermore, I explore whether capitalized development costs (DC) and expensed R&D have a similar impact on the firm's future innovation.

R&D, especially the capitalized DC, provides future benefits to firms which qualifies as an asset and should be capitalized[2]. Because IFRS distinguishes between capitalized DC and expensed R&D, accounting for R&D under IFRS provides an opportunity to examine whether capitalized DC and expensed R&D are associated differently with firms' performance. Prior research finds that capitalized R&D is more informative and more value relevant than expensed R&D (Lev & Sougiannis,1996; Han & Manry, 2004). However, other papers identify no differences or find opposite results that capitalized R&D are not as informative or value relevant as the expensed R&D. Cazavan-Jeny, Jeanjean, and Joos (2011), using a French setting where managers can voluntarily choose to capitalize R&D, find that the decision to capitalize R&D is generally associated with a negative or no impact on future performance. They argue that their result suggest that management is unable to truthfully convey information about future performance through its decision to capitalize R&D.

[2] The FASB's Concept Statement No. 8, Elements of Financial Statements defines as assets as "a present right of the entity to an economic benefit." The IASB Conceptual Framework for Financial Reporting offers a similar asset definition as "An asset is a present economic resource controlled by the entity as a result of
past events. An economic resource is a right that has the potential to produce economic benefits."

Unlike previous research that focuses on the relationship between R&D and firm financial performance, I explore the relationship between R&D and a nonfinancial performance measure as captured by innovation. Innovation is the direct product of the research and development activity and is not impacted by noise such as macro economy which influences the financial performance measures. Thus, as a non-financial performance measurement, innovation might be better in capturing firms R&D outcomes than the financial performance measures.

I measure a firm's innovation as the firm's total patent counts and total patent citations, following the economic literature (Hall et al., 2010). A patent is the foundation of a new product and marks the transition of an idea or finding to an actual product or process. Patent counts are a common measure used in the economic literature to capture firms' innovation outcomes (Bloom & Van, 2002; Katila, 2000). In addition, patent citations that signal the patent's quality by showing how influential the patent is to the real world, are also used in measuring innovation ability (Chen et al., 2018).

The above paragraphs discuss the two primary motivations for this paper: Providing further evidence on the separate reporting of expensed R&D and capitalized R&D, and providing an alternative measurement of R&D productivity via innovation compared to conventional financial performance measures. Additionally, I explore the data validity issue in previous research on R&D capitalization. The current year capitalized DC data is not readily available in mainstream commercial database. Using gross development costs assets or estimating current year development cost computed as the difference of current year's and previous year's gross development costs assets can lead to the invalid analysis conclusion. To ensure my data is accurate, I hand-collect capitalized DC and expensed R&D from financial statements for high tech firms in European countries from 2005 to 2012 where the firms' financial data are available in the Compustat Global. I choose the setting in Europe because EU mandated IFRS adoption in 2005 and European Union will give me a sample relatively larger than a single country.

I use high tech firms because they have high R&D intensity and research and development are crucial to high-tech firms' business. Compared to other industries, high tech firms usually have more detailed R&D costs disclosure with better data availability for my research. One of the reasons that prior research finds no result of R&D on the firms' performance could be due to the fact that they are using a broad industry sample where R&D could be less important compared to other intangibles such as brand name, goodwill and trademarks.

My sample consists of high-tech firms' data in 16 major European Union (EU) countries from 2005 to 2018[3] which includes 1,575 observations. Capitalized DC and expensed R&D costs are hand collected for EU high-tech firms from 2005 to 2012. Total patent counts and total patent citations for one to six-years forward are used to measure firms' innovation ability. Patent data are from 2005 to 2018 and obtained from European Patent Office (EPO)'s PATSTAT global database which contains bibliographical data relating to more than 100 million patent documents from leading industrialized and developed countries.

As IFRS requires DC to be capitalized if a firm can use those costs to complete "the intangible asset" and has shown "its ability to use or sell" that asset (IAS 38),

[3] I require the firms' data to be available on Compustat Global at least for one year from 2005-2012. I stopped my hand-collection of R&D data in 2012 fiscal year. I started with all European Union countries, but after controlling for the variables' availability, only 16 EU countries have observations.

capitalized DC represent successful R&D that are expected to have a stronger link than expensed R&D with future performance. To test this, I estimate an OLS regression with patent counts and citation counts as the dependent variable and with both current year capitalized DC and expensed R&D as independent test variables. Results suggest that both the current year's capitalized DC and expensed R&D are positively associated with total patent counts and citation counts. Moreover, capitalized DC have a larger positive impact on innovation than expensed R&D. First, I run the OLS regression with firms' cumulative years patent counts as the dependent variable and capitalized DC and expensed R&D as the independent variables. The median effect shows that one million euro of capitalized DC (expensed R&D) is related to 9.335% (3.488%) change in one year patent counts. When examining the two R&D costs' different impact on innovation, I find that, by median effect, one dollar spent on capitalized development costs will have 167% greater impact on firms' one-year patent generating than one dollar of expensed R&D, and the differences decrease with time. In 6 years, patent counts, $1 investment on capitalized DC will have 92.88% more impact on firms' patent counts than $1 investment on the expensed R&D.

Then, I run the OLS regression where the dependent variable is the cumulative-years-patents' cumulative-years citations and independent variables are the current year capitalized DC and expensed R&D. The patent citations regressions results are similar to the results of the patent counts regressions. For current year patents, the median effect of one dollar of capitalized R&D on one-year citations (6-year citations) is 102.8% (121.83%) higher than the expensed R&D. When cumulative years patents are examined, the difference becomes even larger. For five-years cumulative patents, the median effect of one dollar of capitalized R&D on one-year citations counts patent citations is 220% higher than the expensed R&D.

Thus, my OLS regression provide evidence that R&D investment relates to firms' future innovation, and capitalized DC, have a higher positive impact on firms' innovation than expensed R&D. My paper provides evidence that fundamental differences exist between firms' capitalized DC and expensed development costs, where capitalized development costs are the more successful R&D, and are more value relevant than the expensed R&D. My result is consistent with R&D treatment under IFRS where those successful development costs are capitalized and other less successful R&D costs are expensed.

This paper contributes to the existing literature by providing additional evidence on informativeness and predictive power of R&D costs under IFRS, which allows managers to capitalize certain DC that would be expensed under US GAAP. IFRS separate the capitalized development costs (successful R&D) from the expensed R&D (less mature R&D). My paper finds that capitalized DC has higher degree of association with firms' innovation than expensed R&D with innovation. There is a necessity for separating capitalized DC from the expensed DC in the financial statement since two different R&D cost are fundamentally different. By showing a higher association with firms innovation capitalized DC, as an asset, have higher certainty of bringing future benefits than expensed R&D.

My paper is one of the first papers to use hand collected large sample of high-tech firms R&D dataset. The inconclusive result in R&D capitalization research could be due to the small sample size and errors of R&D expense in the mainstream database, and could be due to the fact that the previous literature uses a broader industry sample where R&D might not be as important as other intangibles. My paper allows a larger and more accurate R&D data sample in high-tech firms than the mainstream database which helps to confirm the fundamental difference between capitalized DC and expensed R&D.

My paper is one of the first accounting papers to use patents as the non-financial performance measures to examine the R&D capitalization under IFRS. The prior literatures' mixing findings of R&D capitalization under could be due to the complexity in measuring R&D's performance using financial measures. Financial measures could contain other noises such as macro market influences and R&D returns takes a long-time period which makes financial measures not perfect in measuring the R&D investments' impact on firms' future performance. In this paper, I used innovation proxied by patent counts and patent citations to avoid the noise in financial performance measures.

The rest of the paper is organized as follows. Chapter 2 presents the background information and brief overview of the literature review. Chapter 3 describes hypothesis development and research model. Chapter 4 contains the data and sample composition. Chapter 5 presents the analysis results and the main findings. Chapter 6 presents the sensitivity tests. Chapter 7 concludes.

CHAPTER 2

BACKGROUND INFORMATION AND LITERATURE REVIEW

2.1 Background

In today's competitive global economy, R&D investment is a significant engine for growth and has steadily increased each year (U.S. Research and Development Funding and Performance: Fact Sheet, 2021). R&D efforts are the driving force of innovation and, ultimately, economic growth in modern society (Baudry & Dumont, 2006). In 2021, global R&D was estimated to reach $2,440 billion USD, an 18% increase from 2017, just five years earlier. In the US, 2021 R&D investment is projected to be $598 billion USD, which would account for 2.88% of that year's GDP (*R&D Magazine*, 2021). Given the economically significant impact of R&D investment on the global economy, studies have been conducted to investigate the degree and ways of R&D investments' influence on the economy discussed in the literature review below. In 2020, the world's top leading tech firms' R&D accounted for more than 10% of their revenue. For example, in 2020 Amazon's revenue was 386.06 billion USD and its spending on R&D was 42.74 billion USD, or 11% of revenue. In 2020, it was granted 2,244 patents, in advanced technologies such as artificial intelligence (AI), machine learning, and computer vision. Google's parent company, Alphabet, spent 27.57 billion USD on R&D, about 15% of revenue in 2020. It was granted 1,817 patents. Microsoft had 19.27 billion of R&D expenses, 13.5% of revenue, and was granted more than 2,900 patents.[4]

2.2 R&D and Firms' Financial Performance

R&D expenditures are considered investments in intangible assets that contribute to the firms' long-term growth (Chan et al., 2001). Successful investment in R&D helps firms create innovative products and services and gain a competitive advantage over other firms (Ehie & Olibe, 2010). Investments in intangible assets such as R&D, brand names and patents can enhance firms' value (Sougiannis, 1994; Hall & Martin, 2005). Griliches (1981) finds a positive relationship between R&D expenditures and firms' market value. The literature on R&D capitalization finds that R&D capitalization offers extra insight to investors and limits the information asymmetry between firms and outside investors. Aboody and Lev (1996) using US sample show that both annual capitalization amount and the cumulative software asset are positively and significantly associated with stock returns and prices, respectively. Givoly and Shi (2008) show that IPO underpricing is significantly and materially smaller for firms that capitalize software development costs than for firms that expense software development costs.

Other research finds evidence to the contrary or no results on the relation between R&D and the firms' profitability. Kotabe et al. (2002) documented a nonsignificant, negative connection between concurrent ROA and R&D intensity by running time series cross-sectional regression of R&D on ROA data on 49 US companies in 12 different industries from 1986-1993.

The inconclusive results or failure to find the positive relationship between the R&D and firms' future performance could be because R&D has a more uncertain and

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[4] https://www.nasdaq.com/articles/which-companies-spend-the-most-in-research-and-development-rd-2021-06-21

complex return than tangible assets. Kothari et al. (2002) examine the unpredictively of future benefits and firms' R&D and find a positive relationship between R&D investments and volatility of firms' future earnings. Due to the unpredictability and complexity of R&D efforts' future outcomes, the market may fail to reward long-term investment in R&D (Hall, 1993).

Firms' innovation, proxied by patent counts and patent citations is an alternative and a more direct measure of the firms' R&D activity than the financial performance measures. Financial performance measures contain noise such as macro-economic factors, firms' internal efficiency which might lead to inconsistent results when measuring firms' R&D output. Patents are the direct products of firms' R&D activity. Patents protect firms' right to benefit from the R&D investment. Using R&D investments, a patent turns ideas and knowledge into real world applications. Patent counts show how productive R&D investment are. Highly cited patents are those patents that have larger real-world applications and impacts. Thus, patent counts and patent citations as innovation measures, signal firms' future benefits and can be used as alternative measurements of firms' R&D results. I argue that high R&D intensive firms' innovation is directly linked with firms' R&D investments (the beginning of the R&D investment cycle) and closely linked with the firms' long-term performance (the ending result of R&D investment cycle). Thus, comparing with financial measures such as returns or earnings, innovation could better reflect high-tech firms' investment's impact on firms' long-term success. Thus, innovation indicators such as patents or citations, can be used to provide evidence of R&D's impact on firms' future performance.

2.3 Prior Literature on R&D Capitalization

Previous research that studied the R&D capitalization provided contradictory evidence on the informativeness of R&D costs.

Previous research that studied the R&D capitalization before 2005 IFRS adoptions provided contradictory evidence on the informativeness of R&D costs. Lev and Sougiannis (1996) use estimated R&D capitalization in the US finding that off-balance sheet R&D assets provide investors with reliable and relevant information. Han and Manry (2004) using a Korean sample, find that R&D expenditures are positively associated with stock prices suggesting that investors act as if they capitalize R&D as intangible assets. Hughes and Kao (1991) using an analytical model, find that capitalization is more informative than expensing and capitalization can be constructed as an informative signal for R&D activity results. Healy, Myers, and Howe (2002), using a simulation model for a pharmaceutical R&D program, show that the successful efforts method of capitalization can provide information benefits relative to immediate expensing. In contrast, Zhao (2002), using 1990 to 1999 data in France, Germany, UK and the US, find that the allocation of R&D costs between capitalization and expense increases the value relevance of R&D reporting in France and the UK (voluntary capitalizing countries). However, Zhao (2002) finds predicted value of voluntary R&D capitalization as a percentage of R&D intensity has a negative effect on the stock price in the UK, which means R&D expenses are not value relevant in the expected direction. Oswald (2008) using a 1990-2004 UK sample does not find a difference between the R&D expenses and R&D capitalizer’s adjusted R-square of returns test and book-value test which Oswald concludes that there is no difference of firms' value relevance in choosing R&D expensing and capitalizing.

Studies that examine the value relevance of capitalized and expensed R&D under IFRS have also provided contradictory results. Using a UK sample from 2006 to 2008, Tsoligkas and Tsalavoutas (2011) find that after IFRS adoption, the capitalized R&D positively correlate to market values while expensed R&D costs negatively correlate with market value under IFRS. Using a voluntary R&D capitalization treatment setting in France, Cazavan-Jeny, Jeanjean, and Joos (2011) using firms listed in Paris Stock Exchange from 1992-2001 show that the decision to capitalize R&D is generally associated with a negative or neutral impact on future ROA and future sales growth. Shah, Liang and Akbar (2013) examine significant positive relationships between capitalized R&D and fail to find the value relevance of the expensed R&D data using UK sample. Therefore, whether R&D capitalization versus expensing is informative remains an open question, particularly given the IFRS standard.

2.4 R&D & Patents

R&D costs are the inputs to the innovative process (Beneito, 2006), while patent counts (citations) are measures of innovation output (Kleinknecht et al., 2002). Patents, generated by the firm's innovation process, might signal the firm's future ability to benefit from its innovation. A patent, granted by national patent offices, is a legal property right to an invention. A patent gives its owner sole rights (for a specific duration) to exploit the patented invention; at the same time, it discloses the details of the patent to allow broader social use of the discovery (Oslo Manual, 2018).

Through innovation, firms can either introduce new products with premium prices, or improve the efficiency in process and reducing the firms' costs. Patent statistics are increasingly used as indicators of the output of research activities. For example, the number of patents granted to a given firm may reflect its technological dynamism (Oslo Manual, 2018; Manual, O. P. S., 2009). As the outcome of firms' R&D, patents are an indicator of a firms' realized benefit of R&D. Thus, the patent counts as a long-term non-financial performance measure (Hall et al., 2010; Burrus et al., 2018) and could be used to supplement the financial measures to evaluate firms' outcomes of the innovation process and overall performance.

Numerous factors such as firms' business processes, customer relationships, and intangibles such as goodwill and trademarks can influence firms' financial performance. Thus, financial performance can be a noisy measurement of firm's R&D performance. Compared with the relationship between R&D and firms' financial measures, patents are expected and more direct outcomes of R&D activities. Thus, the relationship between R&D and patents is expected to be less noisy than the relationship between R&D and financial performance measures, as financial performance can contain noise such as macroeconomics and the firms' operation efficiency.

I also introduce patent citations, another common measure of firm's innovation, into my analysis because patent counts are also not a perfect measurement of firm's innovation. Not all patents are productive and will generate future benefits to the firm. For example, not all patents will turn into final products. Therefore, citation counts have been used to assess the positive financial performance outcomes of R&D investments (Harhoff et al., 1999; Nagaoka et al., 2010) and are also positively correlated with firms' technological impacts (Aristodemou & Tietze, 2018). More valuable patents that lead to further innovation and real-world applications are cited more often. One quarter of patents receive no citations, whereas only 1% receive more than 100 citations (Hall, 2013). Thus, solely using patent counts as an innovation proxy could not fully reflect firms' innovation ability. Citation counts could supplement total patent counts in showing the patents' productivity. Thus, I will use both total patent counts and patent citations as measures of firm's innovation.

Another reason for the mixed finding in R&D and firm's financial performance could be that the positive impact of innovation on firms' future financial performance is delayed, whereas firms' innovation could be used as a leading indicator of firm's future performances. Ernst (2001) use a time-series cross-section data from 50 German machine tool manufacturers between 1984 and 1992 to show that national and European patent applications have a positive impact on sale increases with a lag of 3 years after the priority year. Katila (2000) examines the time-series of 100 biotechnology firms established between 1980 and 1988 and finds that patent counts and citations can form a performance evaluation system in R&D organizations. Katila (2000) further finds that lags of ten years and longer patent citation shows pharmaceutical firms' innovation output quality. Further, Hall et al. (2005) find a positive relationship between market value (Tobin's q), patent counts, and citations. Thus, past research indicates the innovation, as proxied by patent counts and citations, positively impacts firms' future financial performances in the long term.

2.5 R&D Capitalization under IFRS

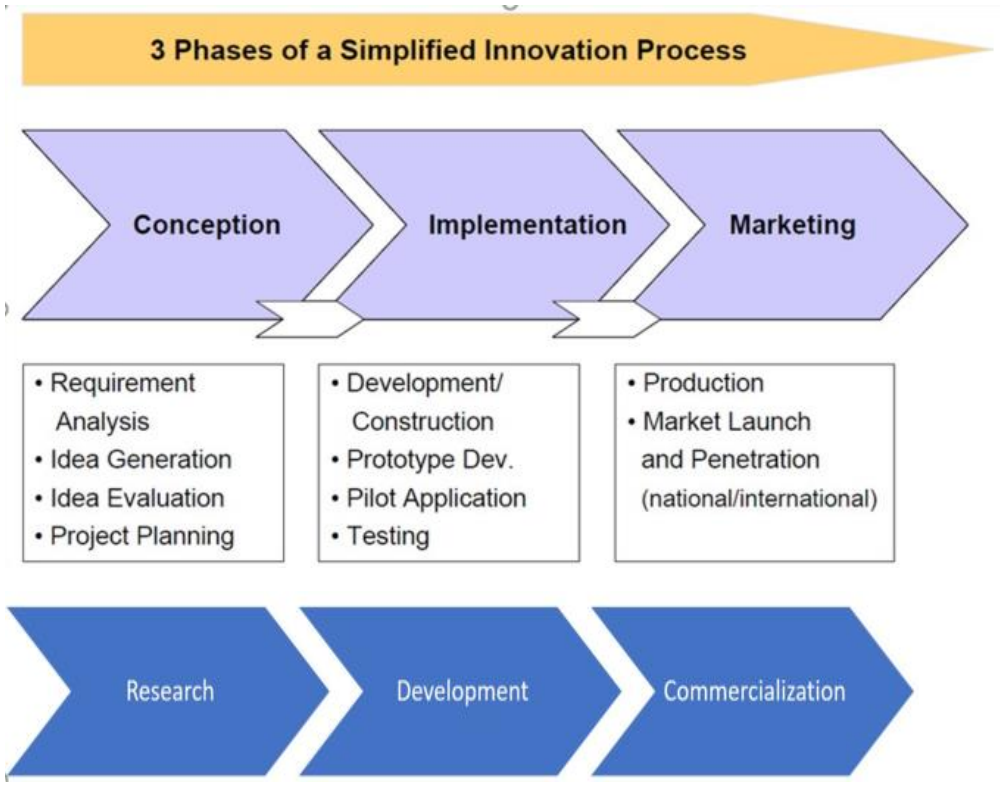
The R&D treatment under IFRS, as found in *IAS 38. Intangible Assets*, requires charging all research cost to expense (IAS 38.54). The development costs are capitalized if and only if a company is able to demonstrate all of the following *(IAS 38.57*):

> *(a) the technical feasibility of completing the intangible asset so that it will be available for use or sale.*
> *(b) its intention to complete the intangible asset and use or sell it.*
> *(c) its ability to use or sell the intangible asset.*
> *(d) how the intangible asset will generate probable future economic benefits. Among other things, the entity can demonstrate the existence of a market for the output of the intangible asset or the intangible asset itself or, if it is to be used internally, the usefulness of the intangible asset.*
> *(e) the availability of adequate technical, financial and other resources to complete the development and to use or sell the intangible asset.*
> *(f) its ability to measure reliably the expenditure attributable to the intangible asset during its development.*

IFRS (*IAS 38.57*) requires that "development costs (DC) are capitalized only after technical and commercial feasibility of the asset for sale or use have been established. This means that the enterprise must intend and be able to complete the intangible asset and either use it or sell it and be able to demonstrate how the asset will generate future economic benefits." Thus, the capitalized DC are expected to have higher certainty of generating future benefits than the expensed R&D.

From Tiwari et al. (2007), the three phases in the innovation process are research, development, and commercialization. I modify Tiwari's et al.'s (2007) innovation process to align with the conceptualization of accounting for R&D and relate it to IFRS accounting. The expanded process is shown in Figure 1.

Figure 1. Tiwari et al.'s (2007) Three Steps of an Innovation Process Mapped into IFRS R&D Accounting Model



IFRS R&D Accounting Model

Tiwari, R., Buse, S., & Herstatt, C. (2007, July). Innovation via global route: Proposing a reference model for chances and challenges of global innovation processes. In *Proceedings of the Second International Conference on Management of Globally Distributed work, Indian Institute of Management, Bangalore* (pp. 451-465)

The initial phase is innovation is research. The company generates ideas, evaluates those ideas, and explores future viable projects in the research phase. Costs incurred in the research phase are related to the original and preliminary investigation undertaken with the prospect of gaining new scientific or technical knowledge and understanding. Thus, the accounting treatment of expensing research costs is consistent with the initial exploration purpose.

Phase two is the development phase. Ideas are evaluated and narrowed down based on viability. The company applies the research findings and invests in the design and engineering of new or substantially improved materials, devices, products, processes, systems, or services. For example, for new or updated products, prototypes are developed and tested with potential customers. Costs incurred in the development phase may or may not be recorded as development costs under IFRS 38. Development costs will be capitalized if meeting the capitalization criteria mentioned in the beginning of Section 2.5 Otherwise, development costs will be expensed if they do not meet the criteria. The final phase, phase three, is commercialization, where the firm brings the product or service to market. This phase extends beyond accounting for R&D under IFRS 38.

Patents are generated throughout all three innovation phases. More patents are expected to be generated when higher R&D input leads to higher innovation. Among all the R&D investments, capitalized development costs (DC) are those R&D meeting technical and commercial feasibility of the asset for sale or use. In other words, capitalized R&D are the “successful” R&D that leads to application, while expensed R&D are those without immediate usage by either the earlier stage of research stage or in the development stage. Thus, capitalized DC are expected to be more closely linked with successful innovation than the expensed R&D. Thus, I predict a stronger link between capitalized DC and total patent counts than between the expensed R&D and total patent counts.

CHAPTER 3

HYPOTHESIS DEVELOPMENT AND RESEARCH DESIGN

3.1 Hypothesis Development

R&D investment, including both those costs that are capitalized and those that are expensed immediately, facilitates the innovation process and promotes firms' future competitiveness and performance, by either introducing new products or improving the operation process. The expensed research costs in the preliminary research phase explore the possibility of an innovation project. Then, costs in the development phase, including those expensed DC and capitalized DC, further develop an innovation project and check its viability. Thus, both expensed R&D and capitalized DC are integrated parts of innovation. With more investment in R&D (capitalized R&D and expensed R&D), one would expect to see increase in the firms' innovation.

As a result, an investment increase in the either capitalized DC and expensed R&D is expected to be associated with higher innovation. Thus, I form my first hypothesis:

H1: Capitalized DC and expensed R&D are both positively associated with firms' innovation.

While both capitalized DC and expensed R&D are expected to be associated with firms' innovation, the two forms of R&D are expected to be different indicators of innovation and firms' future performance. Under IFRS, research and development costs are classified into two phases: research phase and development phase (IAS 38.52). In the research phase of an internal project, an entity cannot demonstrate that an intangible asset exists that will generate probable future economic benefits. Therefore, the research expenditure is recognized as an expense when it is incurred (IAS38.55). The development phase of a project is further advanced than the research phase. In the development phase, an entity can, in some instances, identify an intangible asset based on the criteria in IAS 38 which are based on the expectation that the asset will generate probable future economic benefits, allowing capitalization of related development costs (IAS38.58). Thus, capitalized DC and expensed R&D are expected to capture different economic fundamentals as they are in the various stages of the innovation process. Expensed R&D represents either research costs from the research stage (the initial stage of the innovation process) or development costs from the development stage that have low certainty of future profit generation. Capitalized DC are the successful development costs from the development stage (the second stage of the innovation process). Thus, the capitalized DC, as mature and "successful" R&D in development stage, have higher certainty to generate innovative products or processes that results in patents when compared to the expensed R&D. Thus, compared to expensed R&D, capitalized R&D are expected to be more closely associated with innovation outcomes measured as patents counts and patent citations. Therefore, I form my second hypothesis:

H2: Compared to expensed R&D, capitalized DC have a higher association with firms' innovation, and are associated with higher patent counts and patent citations.

3.2 Research Design

I use Equation (1) and Equation (2) to examine the association between capitalized DC and expensed R&D and firms' innovation providing evidence related to both H1 and H2. The left-hand side of the equations is the innovation proxy. I follow Pakes and Griliches (1980) to use innovation proxy (patent counts or patent citations) as the determinant variables. The right-hand side of the equations includes the two independent variables: capitalized DC and expensed R&D.

$$\sum_{t=0}^{N} pcount_{it} = \alpha + \lambda\, cap\_dc_{it} + \mu\, exp\_rd_{it} + controls + \; country, year\ effect + \varepsilon \ (1)$$

$$\sum_{t=0}^{T} citation\ count_{\,ipt}\ of \sum_{p=0}^{P} patents_{\,ip} = \alpha + \pi\, cap\_dc_{it} + \rho\, exp\_rd_{it} + controls + \; country, year\ effect + \varepsilon \ (2)$$

Where:

$\sum_{t=0}^{n} pcount_{it}$	Log of the cumulative counts of patents published from the current year to the future year p for Firm i
$\sum_{t=0}^{T} citation\ count_{\,ipt}\ of \sum_{p=0}^{P} patents_{\,ip}$	Log of the cumulative citations from current year to year t of the cumulative patents published from current year to year p for Firm i.
cap_dc_{it}	Capitalized development cost for firm i in year t
exp_rd_{it}	Expensed R&D for firm i in year t
$total\_rd_{it}$	Capitalized development costs + expensed R&D for firm i in year t

Control Variables:

at_{it}	Fiscal year-end total assets of Firm i at year t
mtb_{it}	$\frac{CSHOI * fiscal\ year\_end\_price_{it}}{fiscal\ year\ end\ total\ assets_{it} - fiscal\ year\ end\ total\ liability_{it}}$
ROA_{it}	$\frac{Earning\ before\ interest\ and\ tax_{it}}{total\ assest\ at\ the\ fiscal\ year\ end_{it}}$
$leverage_{it}$	$\frac{DEBT_{it}}{AT_{it}} = \frac{(Long-term\ debt\ (DLTT) +\ long\ term\ debt\ due\ in\ one\ year\ (DD1))}{AT_{it}}$ $for\ Firm\ i\ in\ year\ t$
$current\_ratio_{it}$	$\frac{Current\ Assets}{Current\ Liabilities}$
$annual\_return_{it}$	$\frac{p\_fy\_close_{it} /\ AJEXDI_{it} * TRFD_{it})}{(p\_fy\_close_{it-1} /\ AJEXDI_{it-1} * TRFD_{it-1})}$ *100

Table 1: Variable Descriptions

Variable	All dollar values are converted to million euros
$\sum_{i=0}^{n} pcount_{it}$	Log of the n years cumulative patent counts for firm i starting from year t.
$\sum_{y=0}^{n} citation\ count\ of\ \sum_{x}^{n} patents\ _{it}$	Log of the y years cumulative citations of n years patents for firm I starting from year t.
$cap\_dc\_before\ \_log_{it}$	Capitalized development cost for firm i in year t
$exp\_rd\_before\_log_{it}$	Expensed R&D for firm i in year t
$total\_rd\_before\_log_{it}$	Total R&D costs =capitalized development costs+ expensed R&D for firm i in year t
$cap\_dc\ _{it}$	Log of capitalized development cost for firm i in year t
exp_rd_{it}	Log of expensed R&D for firm i in year t
$total\_rd_{it}$	Log of total R&D costs (capitalized development costs+ expensed R&D) for firm i in year t
at_{it}	Total assets of firm i in year t
mtb_{it}	Market to book=$\frac{CSHOI*price\_at\_fiscal\ year\_end}{AT-LT}$
ROA_{it}	ROA =ebit/at for firm i at year t

$leverage_{it}$	Leverage for firm i at year t =DEBT/AT=(Long-term debt (DLTT)+ long-term debt due in one year (DD1))/ AT]
$current\_ratio_{it}$	Current ratio of firm i at year t=$\frac{Current\ Assets}{Current\ Liabilities} = \frac{ACT}{LCT}$
$annual\_return_{it}$	annual_return$_{it} = \frac{p_fy_close_{it}/\ AJEXDI_{it} * TRFD_{it})}{(p_fy_close_{it-1}/\ AJEXDI_{it-1} * TRFD_{it-1})}$ *100
$y1\_pcount_{it}$	Total patent # for year 1 (current year) of firm i at year t
$y2\_pcount_{it}$	Total patent # for year 1-2 of firm i at year t
yn_pcount_{it}	Cumulative patent # for year 1-n of firm i at year t
$count\_cit\_y1\_w\_currenty\_patent_{it}$	Total citation # of year 1(current year) of current year patents of firm i at year t
$count\_cit\_yn\_w\_currenty\_patent_{it}$	Cumulative citation # of year 1 to year n of current year patents of firm i at year t
$count\_cit\_yn\_w\_n\_patent_{it}$	Cumulative citation # of year 1 to year n of $\sum patent\ of\ year 1 - n$ of firm i at year t

The dependent variables are the innovation variables: $\sum_{i=0}^{n} pcount_{it}$, log of the cumulative patent counts for firm i in t years or $\sum_{t=0}^{T} citation\ count_{ipt}\ of\ \sum_{p=0}^{P} patents_{ip}$, log of the t years' cumulative patent citations of p years patents for firm i over the t years. The independent variables are the current year capitalized DC cap_dc_{it} and expensed R&D costs exp_rd_{it}.

Following prior literature of R&D and firms' innovation, I include control variables*: firm size*$_{it}$*, market to book*$_{it}$*, ROA*$_{it}$*, leverage*$_{it}$*, current ratio*$_{it}$*, and annual stock return*$_{it}$. Larger firms tend to have higher R&D innovation capability due to better funding and human capital resources (Plehn-Dujowich, 2009). Higher growth potential firms (proxied by the high market to book), more profitable firms (higher annual stock returns), and firms with better financial stability (liquidity and solvency) have higher innovation ability as those firms can put more resources into innovation. Thus, total patent counts and cumulative patent citations are expected to have a positive and significant relationship with larger firms, higher growth potential with the higher market to book, better financial performance with higher ROA and higher annual stock returns, better liquidity, higher leverage, and higher solvency with higher current ratio.

H1 predicts positive relationships between the two R&D costs (independent variables: capitalized DC and expensed R&D) and innovation variables (dependent variables: total patent counts and total patent citations). Thus, the estimated coefficient of *cap_rd*$_{it}$, λ, and *exp_rd*$_{it}$, μ , in Equation (1) patent counts regression and the estimated coefficient of *cap_rd*$_{it}$,π, and *exp_rd*$_{it}$, ρ, in Equation (2) patent citations regression are predicted to be positive and significant.

H2 compares the degrees of the association of capitalized DC on innovation, and the association of expensed R&D on innovation. I cannot directly compare the estimated coefficients of cap_rd_{it} and exp_rd_{it} in Equation (1) and (2) to evaluate the difference because the independent variables of R&D costs use log-form to mitigate the data heterogeneity issue. Because the cap_rd_{it} and $non\_cap\_rd_{it}$ are both logged, the estimated coefficients λ and μ in Equation (1), π and ρ in Equation (2) capture how 1% change in capitalized R&Dand 1% change in expensed R&D will change the dependent variables. In my sample, a typical firm's capitalized R&D is smaller than its own expensed R&D. The mean (median) of capitalized R&D is 8.78 million (0.67 million) while the mean (median) of expensed R&D is 40 million (5.76 million). A 1% change in capitalized R&D will be smaller than an 1% change in expensed R&D. Thus, direct comparison of the estimated coefficients will make biased conclusions, unless the firm has equivalent portions of capitalized R&D and expensed R&D.

From Table 3, Panel 1, the average capitalized DC are 8.776 million euro and average expensed RD is 39.998 million euro. Thus, 1% increase in capitalized DC equals increase 0.08776 million euros, and 1% increase in expensed R&D equals to increase 0.39998 million euros. To compute the effect per one euro of capitalized versus uncapitalized R&D for an average firm, I divide the estimated coefficient on capitalized R&D by 0.08776 and divide the estimated coefficient on expensed R&D by 0.39998. I then use these amounts per one million dollars spending to compare capitalized DC and expensed R&D's impact on innovation. According to H2, capitalized DC will have a larger association with innovation than the expensed R&D. Thus, I predict that one euro spending on capitalized DC will lead to higher patent counts (citations) than one euro spending on expensed R&D.

CHAPTER 4

DATA AND DESCRIPTIVE STATISTICS

4.1 Data Discussion

My sample consists of 1,575 high-tech firms' observations from 16 European countries. I use high-tech firms for the analysis because high-tech firms are heavily involved in R&D and innovation. R&D and patents are vital to high tech firms' performance comparing to other industry's firms. Using a sample from 1965 to 2015, Aramonte and Carl (2016) find that the R&D intensity has an average of 2.69% for low-tech firms and 12.43% for high-tech firms. In my review of financial statements, the presentation of R&D capitalization in financial statements is more consistent across high tech firms than firms in other industries. Additionally, high tech firms have more patent applications than the normal traditional firms. Following Hall and Vopel (1997), I use four-digit sic codes to identify high tech firms from Compustat Global. A list of high-tech industries' four-digit sic codes is in Appendix A.

Firms accounting variables are from Compustat Global and DataStream. The capitalized DC and expensed R&D data are hand collected from firms' financial statement. The patent data are from European Patent Office (EPO)'s PATSTAT global database. The mandatory adoption of IFRS in EU in 2005 provides an opportunity to examine the impact of R&D capitalization in a cross-country setting under the same accounting standard.

To determine my sample, I started with all Compustat Global high-tech firms using IFRS in all EU countries from 2005 to 2012[5]. I hand collected capitalized DC and expensed R&D data in firm's financial statements. I require the firms to have English financial statements and use IFRS during the sample years. I require the sample firms to have at least one year - non-zero expensed R&D or non-zero capitalized R&D. My sample selection process is shown in Table 2, Panel 1. This returns 1914 observations from COMPUSTAT Global. Further, I require firms to have at least one patent application in 6 years which reduced my sample to 1,615 observations. I also require observations to have the control variables which further limit my sample to 1,575 observations from 269 firms in 16 EU countries.

The 1,575 observations are from 16 European countries from the fiscal year 2005 to the fiscal year 2012: Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom. Though I started with all EU countries in my sample selection process, only the above 16 countries have the required data available. I obtain the firms' list from Compustat Global from 2005 to 2012. I then require the firms to have English financial statements publicly available for manually collecting of firms' current R&D capitalization information. The control variables are obtained from DataStream. The patent data from 2005 to 2018 are obtained from European Patent Office (EPO)'s PATSTAT global database.

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[5] Not all firms in EU adopted in 2005. My sample start in 2005 which gives me a larger sample. Pownall and Wieczynska (2018) find that there are more than 17% of EU firms are non-FIRS adopters by 2012. They conclude that many EU firms do not use IFRS; that some firms exploited definitions, exemptions, and deferrals to avoid adopting IFRS while some firms simply failed to comply with the regulation.

There are two main reasons I use EU data: First, compared to a single country, European data give me a larger sample size. Second, EU's mandatory adoption of IFRS in 2005 give me a chance to study R&D capitalization under IFRS mandatory adoption. The sample distribution by country is presented in Table 2 Panel 2. The UK has the greatest number of observations with 450 (28% of the whole sample), followed by Germany with 317 (20% of the whole sample).

Table 2: Sample Selection and Distribution Process

Table 2 Panel 1: Sample Selection Process

Hand collected sample	**# of observations**
High tech firm-year observations in EU high-tech firms from 2005-2012 that have either nonzero capitalized DC costs or expensed R&D in financial statement notes	1,914
- Observations with zero patents in 6 years	299
= Observations with at least one patents in 6 years	1,615
-Observations missing some control variable	40
Final sample with all control variables	1,575 observation (269 firms)

Table 2 Panel 2: Sample Distribution by County

Country	# of Observations
Belgium	81
Denmark	63
Finland	49
France	134
Germany	317
Greece	5
Ireland	1
Italy	108
Luxembourg	6
Netherlands	45
Norway	50
Portugal	7
Spain	26
Sweden	136
Switzerland	97
United Kingdom	450

4.2 Hand Collected Capitalized Development Costs

Capitalized DC and expensed R&D are hand-collected from firms' financial statements because capitalized DC are not available on commercial databases. One motivation for hand collecting the capitalized DC is to ensure the data is valid. In prior literature, the unavailability of capitalized DC in databases is approached in two ways. The first way is to directly use "accumulated capitalized development cost assets "from the balance as the current year development costs (e.g., Chen et al., 2017). This method uses the inaccurate data item as accumulated DC assets is the total capitalized development costs accumulated across the years. Thus, accumulated DC assets is different from current year's capitalized DC expense which can lead to the failure in reaching an accurate result in analysis as accumulated capitalized DC on the balance sheet is likely higher than current year capitalized DC. As I am interested in assessing the current year's DC and generation of patents and citations in the current and subsequent years, using the accumulated DC is not appropriate. The second commonly used approach is to estimate the current year capitalized DC as the difference between the current year's and the previous year's accumulated capitalized development cost assets. As new DC are capitalized, and prior capitalized DC are being amortized, this approach could understate the amount of capitalized DC in the current year if the amortized capitalized DC is not available or incorrect in the database.

To assess the difference and potential benefit of using hand-collected data, I compare my hand-collected data with capitalized DC estimated as the difference between the current year's and the previous year's cumulative capitalized DC found in DataStream.[6] The following are my observations which I listed in Appendix B.

The estimated capitalized DC sample constructed from DataStream data is a smaller sample size than my hand-collected sample; The estimated DC sample consists of only 342 observations compared to my hand-collected sample of 1,662. A comparison of the 342 observations of estimated capitalized DC with my hand-collected sample is provided in the last section of Appendix B. The estimated sample has high errors compared to my hand-collected sample. Out of the estimated 342 development costs (DC), 27% or 91 out of 342 estimated DC have a smaller than 1% difference with the actual DC. 46% or 157 estimated DC have higher than 20% difference from the actual ones among which 90 estimated DC have higher than 50% error compared to the actual result. Thus, compared to my hand-collected sample, the DataStream sample has fewer observations and a high percentage of errors compared to the financial statements. Therefore, analysis based on the estimated DC is likely not valid due to the significant errors in the estimation process.

4.3 Patent Data

I use two measures of innovation: the total number of patent counts and the total number of citations. One challenging part of data collection is organizing the R&D patent data. I match the high-tech EU firms' name in Compustat database with applicant names in European Patent Office's PATSTAT 2019 patent application database. To consolidate the patent information, I manually collected firm's subsidiaries' information. I combine all subsidiaries' patents into the firm's total patent calculation. Finally, I calculate patent counts and citations following Hall et al. (2007). Here, I constructed cumulative patent

[6] DataStream includes a variable for capitalized development costs which is the accumulated capitalized R&D costs on the balance sheet. Compustat does not have a variable for capitalized development costs.

counts for the current year to cumulative patent counts for the following five years (for a total of six year's cumulative patent counts.

To construct the patent citations variables, I first identified one year to six years cumulative patents. Then, I calculate one year to six years cumulative citations for those cumulative patents. For example, for a firm with a 2005 fiscal year, I constructed patents counts from one year ”2005” patent counts to six years ”2005 to 2010” cumulative patent counts. Then, I constructed cumulative citations for those cumulative patents. For example, for a firm's ”2005 to 2010” six-year cumulative patents' two-year cumulative citations, I first identify all patents generated during 2005 to 2010. For each patent, I then count how many citations within two years after a patent has been generated.

I followed the prior international research to winsorize all variables at (5%, 95%) levels (Gordon & Hsu, 2018). For comparison, I converted all firms' financial data from local currency amounts to euros at the firms' fiscal year-end date exchange rates. Table 3, Panel 1 presents the descriptive statistics for independent variables, capitalized DC and expensed R&D, and control variables. R&D spending has large variation. For the capitalized DC (cap_dc_{it}), the mean (median) is 8.78 million (0.67 million), and 75 percentiles of the capitalized DC is 4.92 million. For the expensed R&D (exp_rd_{it}), the mean (median) is 40 million (5.76 million), and 75 percentile is 29.71. Thus, on average, a firm's expensed R&D is four to five times of its own capitalized DC.

Table 3: Descriptive Statistics

Table 3 Panel 1: Descriptive Statistics for R&D and Control Variables

Variable	N	min	mean	max	p25	p50	p75	Max	cv	sd
cap_dc_before_log	1575	0.00	8.78	78.00	0.00	0.67	4.92	78.00	2.25	19.70
exp_rd_before_log	1575	0.00	40.00	330.96	1.05	5.76	29.71	330.96	2.06	82.30
total_rd_before_log	1575	0.00	57.78	511.00	2.30	8.84	38.20	511.00	2.15	124.20
cap_dc	1575	-16.12	-5.18	4.36	-16.12	-0.41	1.59	4.36	-1.63	8.45
exp_rd	1575	-16.12	-0.10	5.80	0.05	1.75	3.39	5.80	-61.92	6.35
total_rd	1575	-16.12	1.13	6.24	0.83	2.18	3.64	6.24	4.58	5.16
rd_intensity	1575	0.00	0.07	0.24	0.02	0.05	0.10	0.24	0.97	0.07
total_asset	1575	8.16	2997.36	27780.35	63.83	207.45	958.88	27780.35	2.43	7287.61
ceq_conv	1575	4.85	920.46	8716.50	32.72	95.58	420.60	8716.50	2.33	2145.06
p_fy_close	1575	0.17	15.99	107.00	1.70	5.61	15.69	107.00	1.66	26.46
tobinq	1575	0.78	1.75	5.17	1.06	1.38	1.92	5.17	0.63	1.10
market_value	1575	11.44	2062.59	17862.54	51.58	182.72	906.46	17862.54	2.24	4629.07
mtb	1575	0.17	2.11	7.40	0.85	1.53	2.68	7.40	0.89	1.87
roa	1575	-0.32	0.09	0.27	0.06	0.11	0.16	0.27	1.53	0.14
roa_ebit	1575	-0.37	0.04	0.22	0.02	0.07	0.12	0.22	3.01	0.13

leverage	1575	0.00	0.13	0.39	0.02	0.11	0.21	0.39	0.91	0.12
current_ratio	1575	0.75	2.14	6.09	1.26	1.74	2.55	6.09	0.62	1.33
quick_ratio	1575	0.56	1.58	5.18	0.85	1.17	1.82	5.18	0.72	1.14
annual_return	1575	34.81	115.40	261.63	75.72	106.19	141.37	261.63	0.50	57.72
cost_of_capital	1338	0.04	0.51	3.25	0.09	0.20	0.44	3.25	1.57	0.80
sales_1y_future	1544	3.20	2187.16	19953.18	66.24	237.24	881.68	19953.18	2.30	5039.25
sales_2y_future	1504	3.93	2279.38	20390.45	69.13	243.67	928.27	20390.45	2.28	5197.44
sales_3y_future	1457	4.70	2370.44	20652.03	74.75	255.53	1015.69	20652.03	2.25	5322.61

Table 3 Panel 2: Descriptive Statistics for Patent Counts and Patent Citations

variable			N	min	mean	max	p25	P50	P75	CV	sd
Total patent counts (cumulative)	Total patent counts	One-year	1575	0	36.10	254	1	8	32	1.83	65.89
		Two-year	1575	0	74.74	533	3	16	63	1.83	137.01
		Three-year	1575	0	114.23	803	5	24	96	1.82	208.35
		Four-year	1575	1	152.62	1031	8	33	125	1.80	274.22
		Five-year	1575	1	192.29	1278	11	40	159	1.78	342.79
		Six-year	1575	1	232.71	1543	13	49	192	1.78	414.26
Total citation counts (cumulative over years)	Current year patents	One-year Citations	1575	0	3.18	25	0	0	3	2.03	6.43
		Two-year Citations	1575	0	11.15	81	0	1	10	1.90	21.20
		Three-year Citations	1575	0	23.90	169	0	3	21	1.87	44.72
		Four-year Citations	1575	0	39.91	286	0	6	35	1.88	75.09
		Five-year Citations	1575	0	56.87	416	0	8	49	1.90	107.90
		Six-year Citations	1575	0	72.08	521	0	10	65	1.88	135.87
	Two-year patents	One-year Citations	1575	0	6.94	55	0	1	6	2.00	13.84
		Two-year Citations	1575	0	23.46	168	0	3	21	1.87	43.95
		Three-year Citations	1575	0	51.55	377	0	7	44	1.89	97.51
		Four-year Citations	1575	0	85.51	628	1	13	75	1.89	161.99

		Five-year Citations	1575	0	121.14	914	2	18	109	1.92	232.08
		Six-year Citations	1575	0	150.28	1112	2	22	137	1.89	284.68
	Three-year patents	One-year Citations	1575	0	10.66	82	0	1	9	1.96	20.88
		Two-year Citations	1575	0	36.43	262	0	5	32	1.88	68.40
		Three-year Citations	1575	0	77.36	546	1	11	69	1.86	143.99
		Four-year Citations	1575	0	129.45	946	3	19	111	1.89	244.56
		Five-year Citations	1575	0	180.76	1355	3	27	157	1.91	345.13
		Six-year Citations	1575	0	217.78	1562	4	33	194	1.87	406.33
	Four-year patents	One-year Citations	1575	0	14.62	112	0	2	12	1.95	28.57
		Two-year Citations	1575	0	50.06	367	1	7	42	1.90	94.96
		Three-year Citations	1575	0	106.50	782	2	15	89	1.90	202.31
		Four-year Citations	1575	0	174.07	1296	4	25	141	1.91	332.60
		Five-year Citations	1575	0	235.16	1743	6	34	195	1.90	447.29
		Six-year Citations	1575	0	279.17	1982	7	41	237	1.86	518.30
	Five-year patents	One-year Citations	1575	0	18.86	148	0	2	15	1.98	37.43
		Two-year Citations	1575	0	62.05	446	1	9	51	1.88	116.87
		Three-year Citations	1575	0	132.29	979	3	19	103	1.91	252.36
		Four-year Citations	1575	0	210.38	1542	6	31	167	1.90	399.12

		Five-year Citations	1575	0	276.06	1965	7	40	224	1.86	514.81
		Six-year Citations	1575	0	325.12	2221	9	48	274	1.83	593.64

Table 3 Panel 3: Descriptive Statistics for Patent Counts and Patent Citations--Continued

Variable			**N**	**min**	**mean**	**max**	**p25**	**P50**	**P75**	**CV**	**sd**
Log of total patent counts (cumulative over years)		One-year	1575	-9.21	0.39	3.47	5.54	0.00	2.08	3.47	12.41
		Two-year	1575	-9.21	1.71	4.14	6.28	1.10	2.77	4.14	2.46
		Three-year	1575	-9.21	2.51	4.56	6.69	1.61	3.18	4.56	1.45
		Four-year	1575	0.00	3.42	4.83	6.94	2.08	3.50	4.83	0.59
		Five-year	1575	0.00	3.66	5.07	7.15	2.40	3.69	5.07	0.55
		Six-year	1575	0.00	3.85	5.26	7.34	2.56	3.89	5.26	0.53
Log of total citation counts (cumulative over years)	Current year patents	One-year Citations	1575	-9.21	-4.75	3.22	-9.21	-9.21	1.10	-1.12	5.30
		Two-year Citations	1575	-9.21	-2.79	4.39	-9.21	0.00	2.30	-2.05	5.71
		Three-year Citations	1575	-9.21	-1.77	5.13	-9.21	1.10	3.04	-3.30	5.85
		Four-year Citations	1575	-9.21	-1.15	5.66	-9.21	1.79	3.56	-5.16	5.92
		Five-year Citations	1575	-9.21	-0.71	6.03	-9.21	2.08	3.89	-8.36	5.96
		Six-year Citations	1575	-9.21	-0.40	6.26	-9.21	2.30	4.17	-14.80	5.98

	Two-year patents	One-year Citations	1575	-9.21	-3.34	4.01	-9.21	0.00	1.79	-1.66	5.54
		Two-year Citations	1575	-9.21	-1.31	5.12	-9.21	1.10	3.04	-4.29	5.61
		Three-year Citations	1575	-9.21	-0.13	5.93	-9.21	1.95	3.78	-43.50	5.50
		Four-year Citations	1575	-9.21	0.48	6.44	0.00	2.56	4.32	11.53	5.51
		Five-year Citations	1575	-9.21	0.89	6.82	0.69	2.89	4.69	6.22	5.51
		Six-year Citations	1575	-9.21	1.20	7.01	0.69	3.09	4.92	4.56	5.46
	Three-year patents	One-year Citations	1575	-9.21	-2.49	4.41	-9.21	0.00	2.20	-2.23	5.55
		Two-year Citations	1575	-9.21	-0.44	5.57	-9.21	1.61	3.47	-12.39	5.43
		Three-year Citations	1575	-9.21	0.76	6.30	0.00	2.40	4.23	6.80	5.18
		Four-year Citations	1575	-9.21	1.38	6.85	1.10	2.94	4.71	3.71	5.13
		Five-year Citations	1575	-9.21	1.79	7.21	1.10	3.30	5.06	2.84	5.07
		Six-year Citations	1575	-9.21	2.08	7.35	1.39	3.50	5.27	2.40	5.00
	Four-year patents	One-year Citations	1575	-9.21	-1.86	4.72	-9.21	0.69	2.48	-2.96	5.49
		Two-year Citations	1575	-9.21	0.15	5.91	0.00	1.95	3.74	33.99	5.26
		Three-year Citations	1575	-9.21	1.36	6.66	0.69	2.71	4.49	3.60	4.90
		Four-year Citations	1575	-9.21	1.94	7.17	1.39	3.22	4.95	2.50	4.86

		Five-year Citations	1575	-9.21	2.32	7.46	1.79	3.53	5.27	2.06	4.79
		Six-year Citations	1575	-9.21	2.62	7.59	1.95	3.71	5.47	1.78	4.67
	Five-year patents	One-year Citations	1575	-9.21	-1.40	5.00	-9.21	0.69	2.71	-3.87	5.42
		Two-year Citations	1575	-9.21	0.56	6.10	0.00	2.20	3.93	9.17	5.12
		Three-year Citations	1575	-9.21	1.77	6.89	1.10	2.94	4.63	2.64	4.68
		Four-year Citations	1575	-9.21	2.31	7.34	1.79	3.43	5.12	2.02	4.66
		Five-year Citations	1575	-9.21	2.69	7.58	1.95	3.69	5.41	1.70	4.55
		Six-year Citations	1575	-9.21	2.98	7.71	2.20	3.87	5.61	1.47	4.39

Table 3 Panel 4: Correlation between R&D variables

	cap_dc_before_log	*exp_rd_before_log__*	*total_rd_before_log*
cap_dc_before_log	1		
exp_rd_before_log	0.6092	1	
total_rd_before_log	0.736	0.9564	1

Table 3 Panel 5: Correlation between Log of R&D Variables

		cap_dc	*exp_rd*	*total_rd*
cap_dc		1		
exp_rd		0.2034	1	
total_rd		0.4366	0.7913	1

4.4 Descriptive Statistics

Table 3, Panel 2 is the data description of the cumulative patent counts and cumulative patent citations without log transformation. Table 3, Panel 3 is the data description of the log transformed cumulative patent counts and cumulative patent citations. A firm's mean (median) of one-year patents ($y1\_pcount_{it}$) equals 36 (8). The standard deviation is 65.89 which indicates a large variation in the patents amounts. The average (median) cumulative six-year patent count is 232 (49). I calculated patent citations for the current year patents, two-years' cumulative patents (current year + year 2 patents), three-years' cumulative patents (y1-y3 patents), four-years' cumulative patents(y1-y4 patents), five-years' cumulative patents(y1-y5 patents). For each above period, I calculated one year afterwards to six years' cumulative citations. A patent's two-years citation mean (median) is 11.15 (1) with 21.2 standard deviation. A patent's six-years citation mean (median) is 72 (10) while the standard deviation is 135.97.

Table 3, panel 4 shows the correlation between the three R&D variables: total R&D (*total_rd*), capitalized development costs (*cap_dc*), and expensed R&D (*exp_rd*). The correlation between the total R&D and expensed R&D is 0.9564. The correlation between the total R&D and capitalized DC is 0.736 which is lower than the correlation the total R&D and expensed R&D. Capitalized DC and expensed R&D has a correlation of 0.609.

Table 3, panel 5 shows the correlation of log forms of the three R&D variables. Table 3 Panel 4 and Panel 5 both show that the expensed R&D and total R&D have a higher correlation than the correlation between the capitalized R&D and total R&D.

I choose to use the log form of R&D variables and patent variables for my regression because of the heterogeneity issue in the R&D variables. Figure 2.1- Figure 2.3 are the histograms of my original total R&D, capitalized DC and expensed DC, whereas Figure 2.4 - Figure 2.6 are the log transformed counterparts. The original R&D costs are highly skewed while my log transformed data as shown in Figure 2.1-Figure 2.3. Log transformation transforms my skewed data to approximately conform to normality. In other words, compared to the untreated raw variables, my data my log form of the R&D and patent variables are more standardized and normally distributed.

Figures 2: R&D Costs Distribution

Figure 2.1 Histogram of Capitalized Development Costs

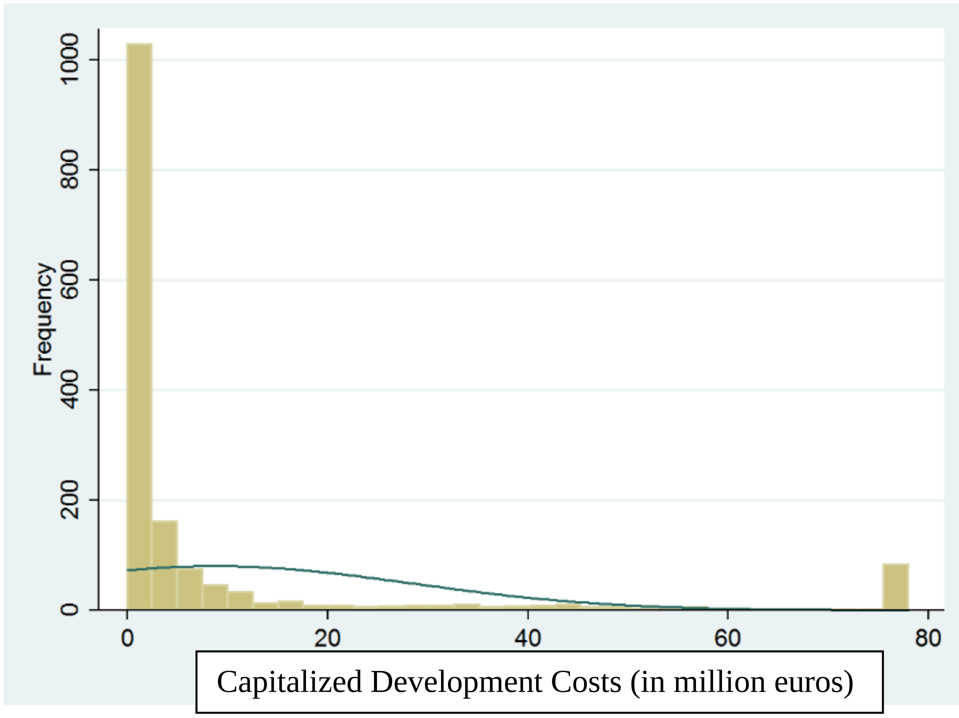


Figure 2.2 Histogram of Expensed R&D

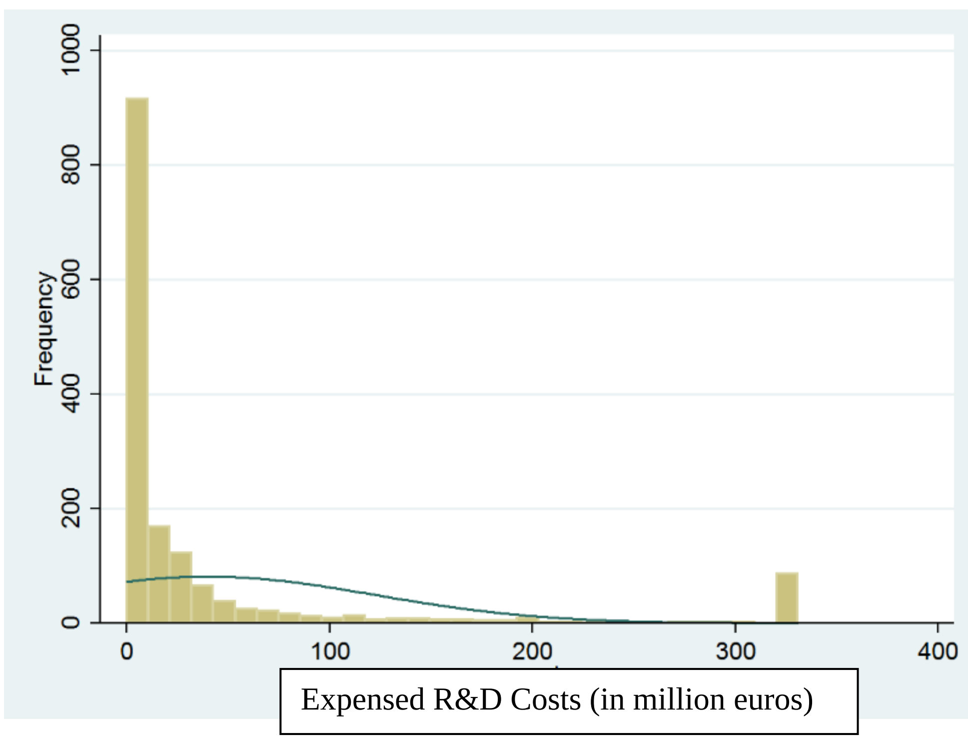


Figure 2.3 Histogram of The Total R&D Costs

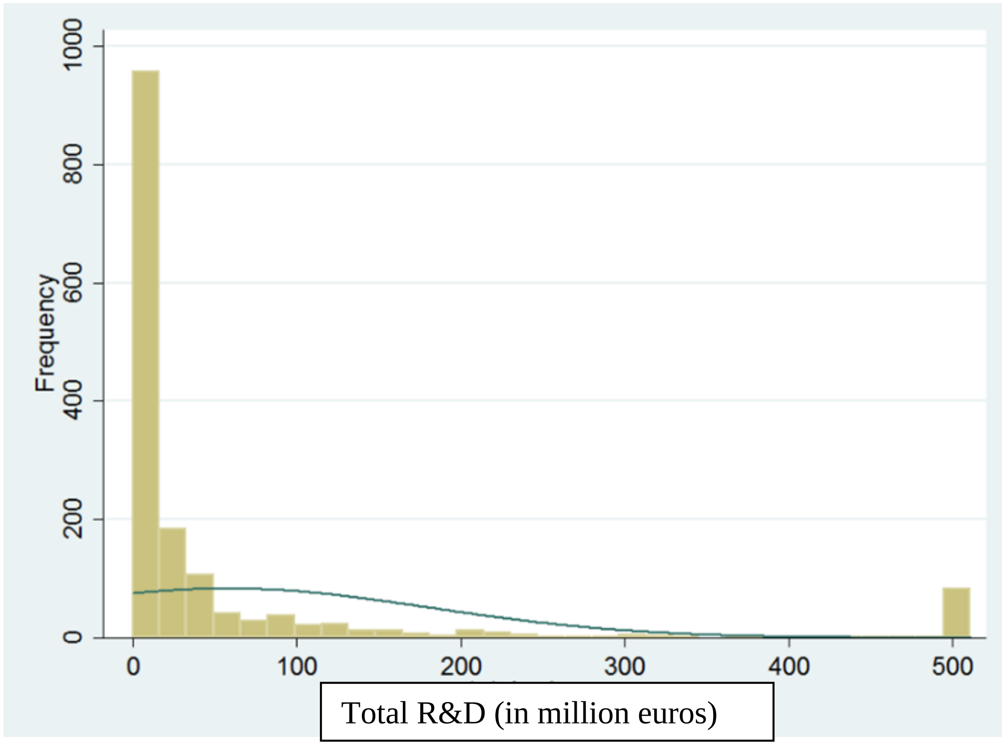


Figure 2.4 Histogram of Log of Capitalized Development Costs

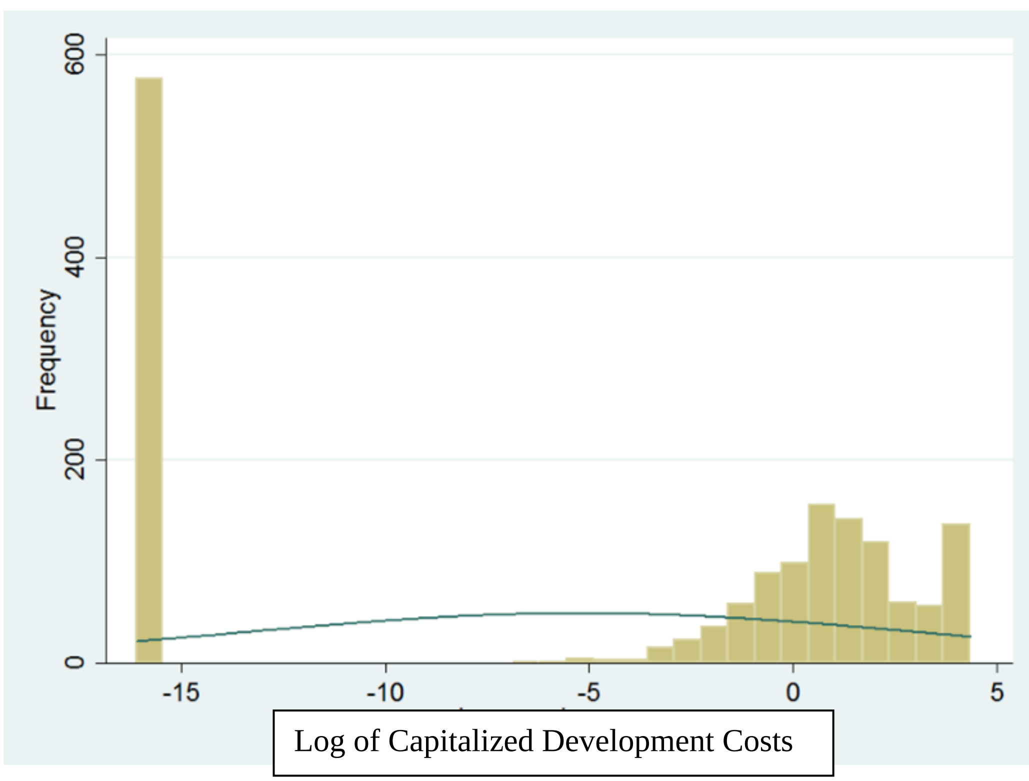


Figure 2.5 Histogram of Log of Expensed R&D

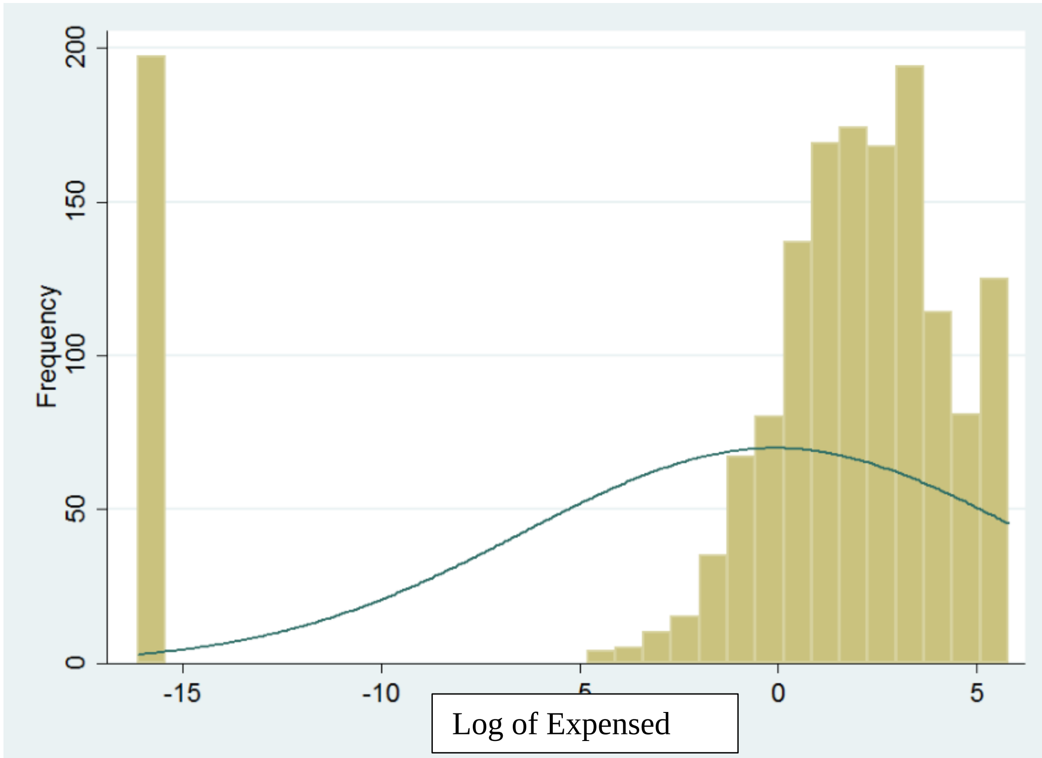
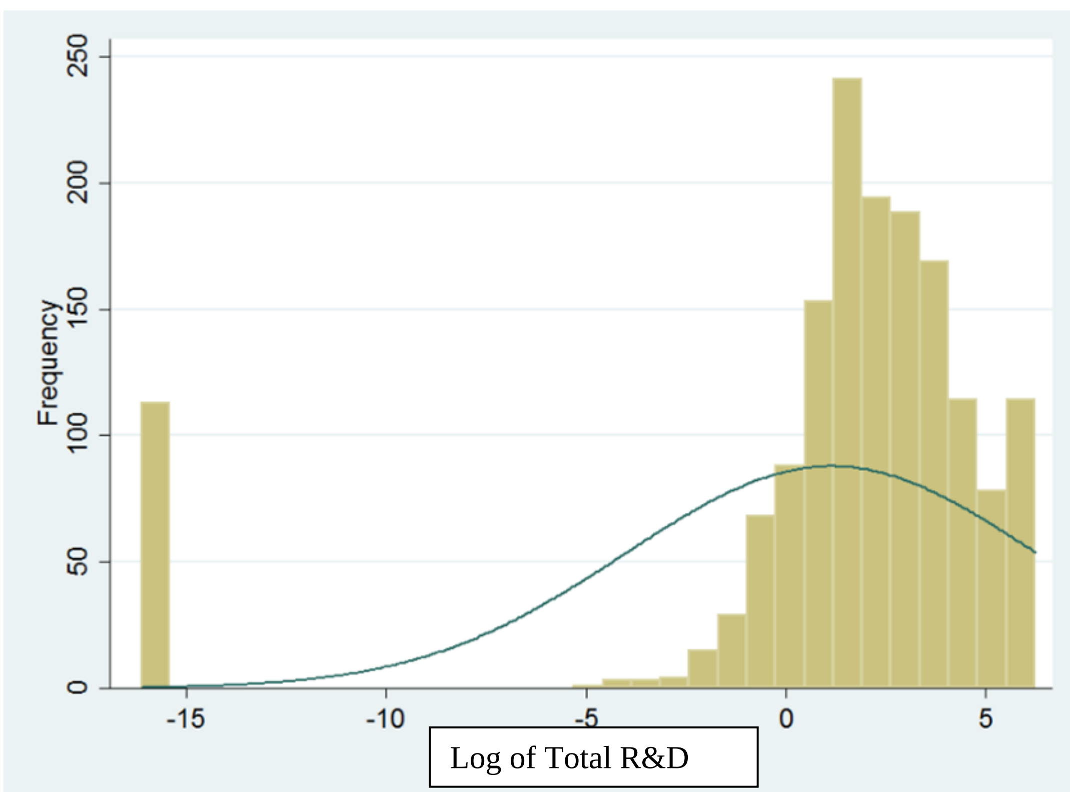


Figure 2.6 Histogram of Log of The Total R&D Costs



CHAPTER 5

EMPIRICAL RESULTS

5.1 OLS Regressions of Patent Counts on R&D Costs

All the estimated regressions are OLS regressions with country, year fixed effect, and robust standard errors. I use country and year fixed effects to control for country specific variations and year specific variations. Table 4 shows the regressions of the two R&D costs on the total patent counts on Equation (1).

Column one in Table 4 shows the estimated regression of current year patent counts on capitalized DCs and expensed costs. Consistent with H1, the estimated coefficients on *cap_dc* of 0.0621, and *exp_rd* of 0.201, are both positive and significant at 1% significance level. Moreover, the difference between the two estimated coefficients are statistically significant at 1% level. Table 4, Column 2 to Column 6 show the regressions of cumulative two years to six years patents counts. The estimated coefficients for the test variables are positive and statistically significant at 1% level, which indicates the current year's R&D spending, including both capitalized DC and expensed R&D, are associated with future six-years patent generation. As the cumulative patent counts years increase from the current year patent counts (*y1_pcount*) to six years' (*y6_pcounts*), the estimated coefficients on *cap_rd* decrease from 0.0621 to 0.0210, and the estimated coefficients on *exp_rd* decrease from 0.201 to 0.0943. The decrease in the estimated coefficients implies as time increases, the current year R&D spending will have less influence in the longer time period's patent generation.

The positive and significant estimated coefficients in Table 4 imply that higher spending on capitalized R&D and expensed R&D is associated with higher patent counts and higher innovation which is consistent with H1.

Table 4: OLS Regressions of Patent Counts on Capitalized DC and Expensed R&D

	Log of n-year patent Counts					
VARIABLES	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.0621*** **	**0.0483*** **	**0.0374*** **	**0.0218*** **	**0.0212*** **	**0.0210*** **
	(0.0142)	**(0.0125)**	**(0.0111)**	**(0.00556)**	**(0.00556)**	**(0.00557)**
exp_rd	**0.201*** **	**0.175*** **	**0.150*** **	**0.0934*** **	**0.0934*** **	**0.0943*** **
	(0.0226)	**(0.0205)**	**(0.0178)**	**(0.00845)**	**(0.00847)**	**(0.00848)**
total_asset	0.000106***	0.000103***	0.0000955***	0.0000818***	0.0000815***	0.0000817***
	(0.0000140)	(0.0000109)	(0.00000940)	(0.00000710)	(0.00000720)	(0.00000731)
mtb	0.0814	0.0737	0.0920*	0.100***	0.102***	0.107***
	(0.0738)	(0.0632)	(0.0523)	(0.0283)	(0.0287)	(0.0289)
roa	4.224***	3.372***	2.502***	1.652***	1.632***	1.612***
	(1.024)	(0.897)	(0.747)	(0.339)	(0.342)	(0.341)
leverage	2.901***	2.421***	1.811**	0.950**	0.869**	0.859**
	(0.979)	(0.844)	(0.727)	(0.394)	(0.398)	(0.398)
current_ratio	0.199*	0.254***	0.224***	0.0645*	0.0665*	0.0788**
	(0.110)	(0.0931)	(0.0777)	(0.0381)	(0.0379)	(0.0374)

annual_return	0.00138	0.00249	0.00330**	0.00140	0.00152*	0.00166*
	(0.00232)	(0.00192)	(0.00156)	(0.000852)	(0.000858)	(0.000858)
Constant	-2.244***	-1.036	0.00816	1.996***	2.213***	2.420***
	(0.768)	(0.672)	(0.583)	(0.297)	(0.300)	(0.297)
Country fixed effects	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y
Observations	1575	1575	1575	1575	1575	1575
R-squared	0.231	0.240	0.247	0.353	0.352	0.353
Robust standard errors in parentheses ***** p<0.01, ** p<0.05, * p<0.1**						

5.2 OLS Regressions of Patent Citations of One-year Patents on R&D Costs

Table 5 Panel 1 to Panel 5 shows the relationship between R&D costs and the cumulative one to six years' patents' n years' citations. In Panel 1, the independent variables are capitalized DC and expensed R&D. The dependent variables are cumulative n years citations of current year's patents where n ranges from one year to five years. Column 1 in Panel 1 is the regression of the one-year citations of the current year patents on capitalized and expensed R&D. The estimated coefficient on *cap_dc* is 0.0573 and *exp_rd* is 0.186. Both estimated coefficients are positive and significant at 1% significance level. Panel 1, Column 2 to Column 6 show the current year patents's 2-year to 6-year citations regressions on the two R&D variables. From Column 1 to Column 6, the estimated coefficients of *cap_dc* are consistent ranging from 0.0573 to 0.0607, and while the expensed R&D estimated coefficients gradually increase from 0.186 to 0.237. The two independent test variables' estimated coefficients are significant in the 1% significance level. The table shows that the associations between the cumulative citations on the current year patents and R&D does not decrease as the years goes by (from year 1 to year 6). For the current year patents, 1% increase in the capitalized development costs leads to 0.06% increase in the cumulative n (2-6) years citations. 1% increase in the expensed R&D costs leads to 0.2% increase in the cumulative n (3-6) years citations. Thus, consistent with H1, both capitalized R&D and expensed R&D positively correlate with the firms' innovation proxied by cumulative citations. The association between cumulative years (1-6 years) citations and firms' R&D (both capitalized DC and expensed R&D) does not decrease as the years goes by, indicating the long-term influence of R&D on the innovation.

Table 5: OLS Regressions of Patent Citations on Capitalized DC and Expensed R&D

Table 5 Panel 1: OLS Regressions of N-year Citations of Current Year's Patents on Capitalized DC & Expensed R&D

	Log of Current Year's Patents' n-year citations					
VARIABLES	**1-year citations**	**2-year citations**	**3-year citations**	**4-year citations**	**5-year citations**	**6-year citations**
cap_dc	**0.0384****	**0.0573*****	**0.0588*****	**0.0588*****	**0.0583*****	**0.0607*****
	(0.0156)	**(0.0166)**	**(0.0168)**	**(0.0171)**	**(0.0172)**	**(0.0173)**
exp_rd	**0.164*****	**0.186*****	**0.222*****	**0.227*****	**0.234*****	**0.237*****
	(0.0222)	**(0.0246)**	**(0.0257)**	**(0.0265)**	**(0.0267)**	**(0.0269)**
total_asset	0.000218***	0.000188***	0.000162***	0.000156***	0.000150***	0.000143***
	(0.0000176)	(0.0000177)	(0.0000180)	(0.0000183)	(0.0000184)	(0.0000186)
mtb	0.127	0.218**	0.259***	0.262***	0.251***	0.246***
	(0.0788)	(0.0856)	(0.0881)	(0.0898)	(0.0905)	(0.0917)
roa	4.621***	5.223***	4.689***	4.864***	4.744***	4.715***
	(0.920)	(1.084)	(1.143)	(1.187)	(1.200)	(1.209)
leverage	1.984*	2.889**	4.012***	3.881***	3.417***	3.424***
	(1.168)	(1.200)	(1.202)	(1.214)	(1.220)	(1.229)
current_ratio	0.233**	0.233**	0.123	0.123	0.0508	0.0671
	(0.106)	(0.117)	(0.122)	(0.126)	(0.128)	(0.128)

annual_return	-0.000910	-0.000434	-0.000464	0.000393	-0.000300	0.000412
	(0.00250)	(0.00274)	(0.00278)	(0.00281)	(0.00284)	(0.00285)
Constant	-6.448***	-5.398***	-4.192***	-3.805***	-3.083***	-2.842***
	(0.837)	(0.903)	(0.923)	(0.930)	(0.930)	(0.939)
Country, Year fixed Effect	Y	Y	Y	Y	Y	Y
Observations	1,575	1,575	1,575	1,575	1,575	1,575
R-squared	0.228	0.230	0.238	0.235	0.235	0.232
Robust standard errors in parentheses ***** p<0.01, ** p<0.05, * p<0.1**						

Table 5 Panel 2: OLS Regressions of N-year Citations of Two-year Patents on Capitalized DC & Expensed R&D

	Log of Two-year Patents' N-year Citations					
VARIABLES	**1-year citations**	**2-year citations**	**3-year citations**	**4-year citations**	**5-year citations**	**6-year citations**
cap_dc	**0.0539*** **	**0.0550*** **	**0.0577*** **	**0.0476*** **	**0.0491*** **	**0.0538*** **
	(0.0161)	**(0.0161)**	**(0.0157)**	**(0.0157)**	**(0.0158)**	**(0.0158)**
exp_rd	**0.173*** **	**0.193*** **	**0.205*** **	**0.205*** **	**0.212*** **	**0.215*** **
	(0.0236)	**(0.0242)**	**(0.0244)**	**(0.0250)**	**(0.0251)**	**(0.0252)**
total_asset	0.000207***	0.000172***	0.000143***	0.000141***	0.000133***	0.000127***
	(0.0000164)	(0.0000155)	(0.0000153)	(0.0000149)	(0.0000150)	(0.0000151)
mtb	0.209**	0.223***	0.224***	0.263***	0.257***	0.239***
	(0.0822)	(0.0843)	(0.0831)	(0.0822)	(0.0816)	(0.0823)
roa	5.162***	6.060***	5.115***	5.258***	5.220***	5.110***
	(1.028)	(1.117)	(1.118)	(1.148)	(1.155)	(1.146)
leverage	2.972**	3.657***	3.518***	3.608***	3.326***	3.583***
	(1.161)	(1.129)	(1.096)	(1.093)	(1.094)	(1.092)
current_ratio	0.351***	0.371***	0.215*	0.177	0.125	0.147
	(0.113)	(0.118)	(0.119)	(0.122)	(0.123)	(0.122)
annual_return	-0.00136	0.000114	0.000913	0.00184	0.000861	0.000851
	(0.00269)	(0.00271)	(0.00260)	(0.00258)	(0.00260)	(0.00260)

Constant	-5.811***	-4.436***	-2.709***	-2.819***	-2.003**	-1.769**
	(0.860)	(0.880)	(0.854)	(0.871)	(0.857)	(0.858)
Country fixed	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y
Observations	1,575	1,575	1,575	1,575	1,575	1,575
R-squared	0.234	0.240	0.247	0.245	0.245	0.240

Table 5 Panel 3: OLS Regressions of N-year Citations of Three-year Patents on Capitalized DC & Expensed R&D

	Log of Three-year Patents' N-year Citations					
VARIABLES	**1-year citations**	**2-year citations**	**3-year citations**	**4-year citations**	**5-year citations**	**6-year citations**
cap_dc	**0.0585*** **	**0.0439*** **	**0.0439*** **	**0.0278***	**0.0286** **	**0.0360** **
	(0.0160)	**(0.0153)**	**(0.0146)**	**(0.0143)**	**(0.0143)**	**(0.0144)**
exp_rd	**0.164*** **	**0.193*** **	**0.196*** **	**0.196*** **	**0.199*** **	**0.199*** **
	(0.0238)	**(0.0236)**	**(0.0231)**	**(0.0236)**	**(0.0235)**	**(0.0236)**
total_asset	0.000188***	0.000159***	0.000136***	0.000133***	0.000127***	0.000120***
	(0.0000159)	(0.0000142)	(0.0000135)	(0.0000132)	(0.0000133)	(0.0000132)
mtb	0.249***	0.284***	0.218***	0.262***	0.261***	0.246***
	(0.0815)	(0.0794)	(0.0763)	(0.0739)	(0.0731)	(0.0739)
roa	5.197***	6.218***	5.164***	5.038***	4.973***	4.279***
	(1.074)	(1.095)	(1.062)	(1.068)	(1.060)	(1.039)
leverage	2.783**	3.067***	2.586**	2.423**	2.205**	2.384**
	(1.135)	(1.078)	(1.023)	(1.009)	(1.001)	(1.001)
current_ratio	0.327***	0.328***	0.221**	0.151	0.127	0.115
	(0.114)	(0.114)	(0.112)	(0.113)	(0.113)	(0.113)
annual_return	0.000611	0.00116	0.00226	0.00216	0.00189	0.00161
	(0.00265)	(0.00254)	(0.00237)	(0.00234)	(0.00228)	(0.00229)

Constant	-5.414***	-3.642***	-1.719**	-1.566*	-0.745	-0.422
	(0.869)	(0.850)	(0.790)	(0.809)	(0.769)	(0.774)
Country fixed	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y
Observations	1,575	1,575	1,575	1,575	1,575	1,575
R-squared	0.234	0.250	0.257	0.253	0.255	0.242

Robust standard errors in parentheses

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

Table 5 Panel 4: OLS Regressions of N-year Citations of Four-year Patents on Capitalized DC & Expensed R&D

	Log of Four-year Patents' N-year Citations					
VARIABLES	**1-year citations**	**2-year citations**	**3-year citations**	**4-year citations**	**5-year citations**	**6-year citations**
cap_dc	**0.0579*** **	**0.0435*** **	**0.0406*** **	**0.0272** **	**0.0290** **	**0.0366*** **
	(0.0158)	**(0.0149)**	**(0.0140)**	**(0.0138)**	**(0.0138)**	**(0.0138)**
exp_rd	**0.163*** **	**0.181*** **	**0.176*** **	**0.178*** **	**0.175*** **	**0.170*** **
	(0.0236)	**(0.0230)**	**(0.0218)**	**(0.0222)**	**(0.0219)**	**(0.0216)**
total_asset	0.000174***	0.000151***	0.000132***	0.000130***	0.000125***	0.000119***
	(0.0000156)	(0.0000136)	(0.0000127)	(0.0000127)	(0.0000127)	(0.0000125)
mtb	0.277***	0.302***	0.209***	0.265***	0.246***	0.239***
	(0.0816)	(0.0786)	(0.0738)	(0.0704)	(0.0708)	(0.0716)
roa	4.617***	5.927***	4.597***	4.015***	4.002***	2.919***
	(1.096)	(1.069)	(1.009)	(0.993)	(0.991)	(0.943)
leverage	2.652**	2.423**	1.874*	1.505	1.214	1.390
	(1.108)	(1.059)	(0.995)	(0.995)	(0.982)	(0.979)
current_ratio	0.287**	0.315***	0.220**	0.140	0.132	0.115
	(0.114)	(0.112)	(0.107)	(0.107)	(0.107)	(0.107)
annual_return	0.00107	0.000926	0.00304	0.00255	0.00218	0.00176

	(0.00262)	(0.00247)	(0.00221)	(0.00219)	(0.00215)	(0.00212)
Constant	-4.940***	-2.830***	-1.181	-0.813	0.157	0.569
	(0.876)	(0.835)	(0.773)	(0.792)	(0.736)	(0.737)
Country fixed	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y
Observations	1,575	1,575	1,575	1,575	1,575	1,575
R-squared	0.231	0.251	0.248	0.241	0.241	0.223
Robust standard errors in parentheses ***** p<0.01, ** p<0.05, * p<0.1**						

Table 5 Panel 5: OLS Regressions of N-year Citations of Five-year Patents on Capitalized DC & Expensed R&D

	Log of Five-year Patents' N-year Citations					
VARIABLES	**1-year citations**	**2-year citations**	**3-year citations**	**4-year citations**	**5-year citations**	**6-year citations**
cap_dc	**0.0577***	**0.0386***	**0.0336**	**0.0219***	**0.0258***	**0.0332**
	(0.0157)	**(0.0145)**	**(0.0133)**	**(0.0132)**	**(0.0132)**	**(0.0131)**
exp_rd	**0.156***	**0.174***	**0.161***	**0.164***	**0.164***	**0.157***
	(0.0234)	**(0.0224)**	**(0.0206)**	**(0.0210)**	**(0.0207)**	**(0.0202)**
total_asset	0.000171***	0.000148***	0.000129***	0.000127***	0.000121***	0.000115***
	(0.0000152)	(0.0000131)	(0.0000120)	(0.0000121)	(0.000012)	(0.0000118)
mtb	0.282***	0.307***	0.207***	0.256***	0.226***	0.216***
	(0.0819)	(0.0770)	(0.0710)	(0.0696)	(0.0694)	(0.0697)
roa	4.289***	6.002***	4.653***	3.802***	3.717***	2.617***
	(1.095)	(1.049)	(0.978)	(0.955)	(0.946)	(0.884)
leverage	1.938*	1.727*	1.254	1.036	0.839	0.977
	(1.092)	(1.043)	(0.956)	(0.962)	(0.945)	(0.934)
current_ratio	0.269**	0.295***	0.200*	0.132	0.127	0.126
	(0.115)	(0.111)	(0.103)	(0.103)	(0.102)	(0.0997)
annual_return	0.00156	0.00119	0.00321	0.00295	0.00262	0.00232
	(0.00259)	(0.00238)	(0.00207)	(0.00210)	(0.00203)	(0.00199)

Constant	-4.613***	-2.209***	-0.689	-0.298	0.781	1.175*
	(0.871)	(0.805)	(0.749)	(0.768)	(0.688)	(0.683)
Country fixed	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y
Observations	1,575	1,575	1,575	1,575	1,575	1,575
R-squared	0.230	0.254	0.246	0.238	0.242	0.225

Robust standard errors in parentheses

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

5.3 OLS Regressions of Patent Citations of Two-year Patents on R&D Costs

Table 5 Panel 2 presents OLS regressions of capitalized DC and expensed R&D on the cumulative future n years' (n=1-6) citations of the two years patents. All the estimated coefficients on the independent variables are statistically significant at 1% significance level. The estimated coefficients on capitalized DC (*cap_dc*) range from 0.0476 to 0.0550 while the estimated coefficients on expensed R&D (*exp_rd*) range from 0.0173 to 0.215. Thus, for the two-year cumulative patents, the future n years cumulative citations (1-6 years) are associated with the current year R&D. Within six years, the association does not decrease as the years goes by.

5.4 OLS Regressions of Patent Citations of Three-year Patents on R&D Costs

Table 5 Panel 3 shows OLS regressions of capitalized DC and expensed R&D on future n years' citations of three-year patents. All the estimated coefficients on the independent variables are statistically significant at 1% significance level. The estimated coefficients on capitalized R&D for the cumulative one-year to cumulative three-year citations are around 0.04 to 0.05. The estimated coefficients on capitalized R&D for the cumulative four-year to cumulative six-year citations are around 0.03 to 0.04. Thus, the impact of current year development costs on the cumulative citations of three-year patents decrease after 3 years. The estimated coefficients of expensed R&D on the three-year patents' n years cumulative citations (n=1-6) are consistent at 0.19 which shows a stable relationship between current year expensed R&D and three-year patents' cumulative six-year citations.

5.5 OLS Regressions of Patent Citations of Four-year/ Five-year Patents on R&D Costs

Table 5 Panel 4 shows OLS regressions of capitalized DC and expensed R&D on n-years' citations (n=1-6) of four-year patents. Table 5 Panel 5 shows OLS regressions of capitalized DC and expensed R&D on n years' citations of five years patents. Thus, all regression results are similar with Table 5 Panel 1 and consistent with H1 that both capitalized R&D and expensed R&D positively impact firms' innovation.

5.6 Summary of The Regressions in Table 4 and Table 5

H2 distinguishes capitalized DC and expensed R&D's association with innovation. In Table 4 and Table 5, the estimated coefficients on the two test variables: *cap_rd* and *exp_rd* are statistically different at 1% significance level. As discussed in Section 4, research design, my independent variables are log-transformed, and their estimated coefficients indicate how 1% change in the independent variables impacts the dependent variable. 1% of capitalized DC on average is 0.0878 million while 1% of expensed R&D on average is 0.4 million. As the expensed R&D is 4.5 times greater than capitalized DC, I cannot directly compare the estimated coefficients of capitalized R&D and expensed R&D in Table 4 and Table 5 to test H2. Thus, to compare the effect of R&D spending capitalized versus expensed on firms' innovation, I divide the estimated coefficients on capitalized R&D in Table 4 and Table 5 with average (median) capitalized DC from Table 3 Panel 1 to obtain the effect per 1 million euro of capitalized DC for an average (median) firm. I divide the estimated coefficients of expensed R&D in Table 4 and Table 5 with average (median) expensed R&D from Table 3 Panel 1 to get the effect per 1 million euro of expensed R&D for an average (median) firm. The results are shown in Table 6.

Table 6: Summary Report of Table 4 and Table 5

Table 6 Panel 1 Summary Report: Impact on Firms' Patent Counts - Capitalized Development Cost vs Expensed R&D

Summary of Table 4: OLS Regressions of Patent Counts on Capitalized DC and Expensed R&D

% change of the total patent counts with 1 million USD increase in Capitalized R&D/ Expensed R&D

		Total Patent Counts					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	**mean effect**	0.7076%	0.5503%	0.4261%	0.2484%	0.2416%	0.2393%
	median effect	9.3347%	7.2603%	5.6218%	3.2769%	3.1867%	3.1567%
Expensed R&D	**mean effect**	0.5025%	0.4375%	0.3750%	0.2335%	0.2335%	0.2358%
	median effect	3.4884%	3.0371%	2.6033%	1.6210%	1.6210%	1.6366%
Capitalized DC/Expensed R&D	**mean effect**	140.80%	125.79%	113.63%	106.37%	103.45%	101.49%
	median effect	267.59%	239.05%	215.95%	202.16%	196.59%	192.88%

e.g., the first cell: the mean effect of capitalized DC on the one-year total patent counts: 0.7076%

it means on average, 1 million $ spend on Capitalized R&D will lead to 0.7076% increase in total number of R&D counts

Table 6 Panel 2 Summary Report of Table 5 Panel 1-Table 5 Panel5

Impact on Firms' Cumulative Years Citations: Capitalized R&D vs Expensed R&D
change of # citations with 1 million USD increase in Capitalized R&D/ Expensed R&D

Current year patents' n-year citations

		1 year	2 years	3 years	4 years	5 years	6 years
Capitalized DC	**mean effect**	0.4375%	0.6529%	0.6700%	0.6700%	0.6643%	0.6916%
	median effect	5.7722%	8.6131%	8.8386%	8.8386%	8.7635%	9.1242%
Expensed R&D	**mean effect**	0.4100%	0.4650%	0.5550%	0.5675%	0.5850%	0.5925%
	median effect	2.8462%	3.2280%	3.8528%	3.9396%	4.0611%	4.1132%
Capitalized DC/Expensed R&D	**mean effect**	106.71%	140.40%	120.71%	118.05%	113.55%	116.72%
	median effect	202.80%	266.82%	229.41%	224.35%	215.79%	221.83%

		Cumulative 2 years patents n-year citations					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	**mean effect**	0.6141%	0.6267%	0.6574%	0.5424%	0.5594%	0.6130%
	median effect	8.1021%	8.2674%	8.6733%	7.1551%	7.3805%	8.0870%
Expensed R&D	**mean effect**	0.4325%	0.4825%	0.5125%	0.5125%	0.5300%	0.5375%
	median effect	3.0024%	3.3495%	3.5578%	3.5578%	3.6793%	3.7313%
Capitalized DC/Expensed R&D	**mean effect**	141.99%	129.88%	128.28%	105.82%	105.55%	114.04%

	median effect	269.85%	246.82%	243.78%	201.11%	200.59%	216.73%

		Cumulative 3 years patents' n-year citations					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	**mean effect**	0.6666%	0.5002%	0.5002%	0.3168%	0.3259%	0.4102%
	median effect	8.7935%	6.5989%	6.5989%	4.1788%	4.2991%	5.4114%
Expensed R&D	**mean effect**	0.4100%	0.4825%	0.4900%	0.4900%	0.4975%	0.4975%
	median effect	2.8462%	3.3495%	3.4016%	3.4016%	3.4537%	3.4537%
Capitalized DC/Expensed R&D	**mean effect**	162.57%	103.66%	102.08%	64.64%	65.50%	82.45%
	median effect	308.95%	197.01%	193.99%	122.85%	124.48%	156.69%

		Cumulative 4 years' n-year citations					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	**mean effect**	0.6597%	0.4956%	0.4626%	0.3099%	0.3304%	0.4170%
	median effect	8.7033%	6.5388%	6.1029%	4.0886%	4.3592%	5.5016%
Expensed R&D	**mean effect**	0.4075%	0.4525%	0.4400%	0.4450%	0.4375%	0.4250%
	median effect	2.8289%	3.1413%	3.0545%	3.0892%	3.0371%	2.9504%
Capitalized DC/Expensed R&D	**mean effect**	161.88%	109.53%	105.13%	69.64%	75.52%	98.12%

	median effect	307.66%	208.16%	199.80%	132.35%	143.53%	186.47%

Cumulative 5 years patents' n-year citations

		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	**mean effect**	0.6574%	0.4398%	0.3828%	0.2495%	0.2940%	0.3783%
	median effect	8.6733%	5.8022%	5.0506%	3.2919%	3.8782%	4.9905%
Expensed R&D	**mean effect**	0.3900%	0.4350%	0.4025%	0.4100%	0.4100%	0.3925%
	median effect	2.7074%	3.0198%	2.7942%	2.8462%	2.8462%	2.7247%
Capitalized DC/Expensed R&D	**mean effect**	168.57%	101.10%	95.11%	60.86%	71.70%	96.37%
	median effect	320.36%	192.14%	180.76%	115.66%	136.26%	183.16%

Table 6 Panel 1 summarizes Table 4 results and compares the associations of capitalized DC and patents counts with the associations of expensed R&D costs and patent costs. Column 1 shows the mean and median effects of capitalized R&D and expensed R&D on one-year patent counts. The following shows I calculate the mean (median) effect of one million increase in capitalized DC on the firms' one year patent counts:

In Table 4, my dependent variables are log-transformed patent counts and my independent variables are log-transformed capitalized DC and expensed R&D. The original estimated coefficient on cap_dc in Table 4 shows 1% change in capitalized development costs leads to "original coefficient*1%" change in total patent counts. From Table 3 Panel 1, the mean of capitalized DC is 8.78 million. Thus, 1% change in mean capitalized DC is 0.0878 million. The estimated coefficient of capitalized DC in Table 4, Column 1 is 0.0621. On average, 1% increase in capitalized DC (0.0878 million increase) will lead to 0.000621(0.0621*1%) increase in the one-year total patent counts. Thus, according to the mean effect, 1 million increase in capitalized DC will lead to 0.7076% (0.000621/0.08776) increase in the one-year patent counts. According to the median effect, 1 million increase in capitalized DC will lead to 9.3347% (0.000621/0.00665) increase in the firms' one-year patent counts.

On average, 1 million euro of expensed R&D results in 0.5025% increase in a total one-year patent counts. Thus, the impact of capitalized R&D is 41% [(0.7076-0.5025)/0.514] larger than the expensed R&D on the patent generating in one-year patent counts analysis.

Using the medians to examine the difference in one year, 1 million more investment in the capitalized R&D will result in 9.3347% more patents. 1 million more invest in the expensed R&D results in 3.4884% more patents. Here the patent generated of capitalized DC are 2.68 (9.3347%/3.4884%) times that of expensed R&D based on median effect. The difference of the mean effect of capitalized R&D over expensed R&D became smaller: 1.41 times in year 1 to 1.02 times in year 6. However, median effect of capitalized DC over expensed R&D persist: one year, 267.59% to six years, 192.88%. Based on median effect, capitalized R&D have more than 2 times patent generating ability than the expensed R&D from one year to four years.

Table 6 Panel 2 compares the difference of capitalized DC and expensed DC on firms' cumulative citations based on Table 5 Panel 1- Panel 5.

The results are consistent with Table 6 Panel 1. The positive association between capitalized DC and future total patent citations is more robust in magnitude than the association between the expensed DC and the future total patent citations for an average firm. For current year patents of the cumulative n-year citations, the mean and median effects of capitalized DC are both higher than expensed R&D. When I divide the mean effect of capitalized DC over the mean effect of the expensed R&D, the capitalized DC/ expensed influence on current year patents' cumulative n years' citations range from 107% to 140% of the expensed R&D. Moreover, when I divide the median effect of capitalized DC over the median effect of the expensed R&D, the capitalized DC influence/ the expensed R&D on current year patents' cumulative n years citations range from 202.80% to266.82%. Thus, from median effect, comparing with expensed R&D,

firms' capitalized DC will have more than two times impact on current year patents cumulative years citations.

The cumulative 2-year patents' cumulative n-year citations regressions show similar results. The median effect of the capitalized DC influence over expensed R&D influence range from 200.60% to 269.85%. Thus, from median effect, comparing with expensed R&D, firms' capitalized DC will have more than two times impact on two years patents' cumulative years citations.

The cumulative three- (four-) year patents' cumulative n-year citations regressions show some difference. The mean effect of capitalized R&D/ expensed R&D declined over time from 162.57%in one-year citations to 64.64% in five years' citations and increased to 82.45% in six years citations. The median effect of capitalized R&D/ expensed R&D declined over time from in 308.95% one year to 122.85% in four years and 124.48% in five years, and then returned to 156.69% in six years Based on median effect, the result continued to indicate that capitalized DC have higher patent citations than expensed R&D. Cumulative four- (five-) year patents citations regression still presents the similar result. Overall, based on median effect, compared with expensed R&D, capitalized DC are associated with two times higher innovation ability as presented by both patent counts and patent citations.

CHAPTER 6

SENSITIVITY TESTS

Kim and Marschke (2004) find that the increase in R&D expenditure accounts for most effect of the overall rise in patents 1983 to 1992 in US firms. I first follow Kim and Marschke to examine the relationship between innovation and total current year R&D costs to confirm the positive relationship between total R&D and innovation proxied by patent counts and citations. I replace the independent variables in Equations (1) and (2) with the total current year R&D costs. Table 7 summarizes the regression results showing a positive relationship between firms' total R&D costs and innovation (proxied by patent counts and patent citations). The estimated coefficients on total R&D costs are always positive and significant at 1% significance level. A 1 % increase in total R&D costs is associated with 0.289% increase in one-year patent counts, 0.247% increase in two-year patent counts, 0.205% increase in three-year patent counts, 0.135% increase in four-year patent counts, 0.133% increase in five-year patent counts and 0.133% increase in six-year patent counts. For patent citations, a 1% increase in total R&D costs is associated with a 0.25 % or more increase in the cumulative patent citations.

Table 7: OLS Regressions of Innovation Variables on Total R&D Costs

Summary of OLS Regressions of Log (n years' # of patents) on Log (total R&D)

	Total N-year Patent Counts					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Total R&D	0.289***	0.247***	0.205***	0.135***	0.133***	0.133***

Summary of OLS regressions of log (n years' # of citations) on log (total R&D)

	Current Year Patents' N-year Citations					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Total R&D	0.253***	0.305***	0.342***	0.345***	0.353***	0.355***

	Cumulative Two Years Patents' N-year Citations					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Total R&D	0.281***	0.308***	0.316***	0.306***	0.313***	0.316***

	Cumulative Three Years Patents' N-year Citations					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Total R&D	0.274***	0.301***	0.297***	0.288***	0.287***	0.286***

	Cumulative Four Years Patents' N-year Citations					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
lg_total_rd	0.281***	0.287***	0.274***	0.271***	0.261***	0.257***

	Cumulative Five Years Patents' N-year Citations					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
lg_total_rd	0.269***	0.275***	0.247***	0.246***	0.240***	0.234***

My data has the large number of zeros in both dependent and independent variables. My dependent variables: patent counts and patent citations are censored above zeros for a significant number of observations. To deals with the censored dependent variable, I replace my OLS regressions with Tobit model to mitigate the censored dependent. Table 8 Panel 1 shows the Tobit model with n years' patent counts (1-5 years) as the dependent variable, and capitalized DC and expensed DC as the independent variables. The estimated positive coefficients of both independent variables are positive. The estimated coefficients of the capitalized DC of 2 years, 3 years and 4 years patent counts regressions are statistically insignificant while the estimated coefficients of expensed R&D in all six regressions are statistically significant at 1% significance level. F tests show statistically insignificant between the capitalized DC and expensed DC's estimated coefficients.

Table 8: Tobit Regressions of Innovation Variables on Capitalized DC and Expensed R&D

Table 8 Panel 1: Tobit Regressions of Log (N Years' Patent Counts) on Log (Capitalized DC) & Log(Expensed R&D)

	Log (N Years Patent Counts)					
VARIABLES	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.511****	**0.853***	**1.085**	**1.222**	**1.645**	**2.137***
	(0.232)	**(0.450)**	**(0.660)**	**(0.815)**	**(1.008)**	**(1.204)**
exp_rd	**2.473*****	**4.418*****	**6.034*****	**6.757*****	**8.436*****	**10.09*****
	(0.338)	**(0.632)**	**(0.895)**	**(1.060)**	**(1.295)**	**(1.543)**
total_asset	0.00498***	0.0104***	0.0159***	0.0209***	0.0263***	0.0321***
	(0.000347)	(0.000712)	(0.00107)	(0.00138)	(0.00172)	(0.00208)
mtb	0.941	2.455	4.669*	7.160**	9.789**	12.29**
	(0.916)	(1.753)	(2.587)	(3.361)	(4.279)	(5.191)
roa_ebit	47.51***	79.30***	105.2***	121.6***	151.7***	178.8***
	(10.25)	(17.97)	(25.08)	(30.02)	(37.41)	(45.04)
leverage	-14.34	-48.58*	-91.70**	-137.2***	-177.9***	-228.8***
	(14.66)	(28.26)	(41.22)	(51.34)	(63.34)	(75.94)
current_ratio	0.979	1.380	0.647	-2.865	-3.899	-4.755
	(1.172)	(2.105)	(2.948)	(3.528)	(4.346)	(5.185)
annual_return	-0.00434	0.000667	0.00279	-0.0331	-0.0337	-0.0185
	(0.0333)	(0.0647)	(0.0959)	(0.122)	(0.151)	(0.182)
Constant	3.507	14.02	32.67	77.79**	93.50**	108.7**
	(11.01)	(21.24)	(30.53)	(37.94)	(46.98)	(55.13)
sigma	58.90***	114.8***	168.1***	210.8***	261.4***	313.9***
	(1.990)	(3.918)	(5.688)	(6.963)	(8.467)	(10.04)
Observations	1,575	1,575	1,575	1,575	1,575	1,575

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

Table 8 Panel 2: Summary Report for Table 8 Panel 1 -Tobit Model

		Log (Total Patent Counts)					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	**mean effect**	5.82%	9.72%	12.36%	13.92%	18.74%	24.35%
	median effect	76.81%	128.22%	163.09%	183.69%	247.27%	321.23%
Expensed R&D	**mean effect**	6.18%	11.05%	15.09%	16.89%	21.09%	25.23%
	median effect	42.92%	76.67%	104.72%	117.27%	146.41%	175.11%
Capitalized DC/Expensed R&D	**mean effect**	94.17%	87.99%	81.95%	82.42%	88.87%	96.52%
	median effect	178.97%	167.23%	155.74%	156.64%	168.89%	183.44%

Table 8 Panel 3: Tobit Regressions of Log (Current Year Patents' N-Year Citations) on Log (Capitalized DC) & Log (Expensed R&D)

	Current Year Patents' N-year Citations					
VARIABLES	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.0547**	**0.138**	**0.265**	**0.363**	**0.462**	**0.527**
	(0.0398)	**(0.0997)**	**(0.191)**	**(0.309)**	**(0.431)**	**(0.536)**
exp_rd	**0.381*** **	**1.023*** **	**2.212*** **	**3.573*** **	**5.029*** **	**6.191*** **
	(0.0669)	**(0.150)**	**(0.289)**	**(0.461)**	**(0.638)**	**(0.784)**
total_asset	0.000629***	0.00173***	0.00338***	0.00558***	0.00794***	0.00991***
	(0.0000454)	(0.000127)	(0.000256)	(0.000426)	(0.000612)	(0.000769)
Mtb	0.207	0.860**	2.080**	3.498**	4.732**	5.805**
	(0.181)	(0.438)	(0.836)	(1.364)	(1.891)	(2.345)
roa_ebit	13.38***	31.36***	54.99***	87.44***	116.9***	145.2***
	(2.707)	(5.948)	(10.78)	(16.98)	(23.19)	(28.34)
leverage	1.211	-0.740	1.412	-3.293	-12.48	-14.04
	(2.720)	(6.564)	(12.46)	(19.97)	(27.90)	(34.45)
current_ratio	0.704***	1.078*	1.150	1.578	1.233	1.576
	(0.263)	(0.609)	(1.158)	(1.844)	(2.559)	(3.109)
annual_return	-0.00118	0.00196	0.000476	0.00916	0.00525	0.0129
	(0.00594)	(0.0150)	(0.0286)	(0.0461)	(0.0650)	(0.0800)
Constant	-5.514***	-7.918	-8.474	-12.42	-10.53	-11.05
	(2.118)	(5.440)	(10.25)	(16.40)	(22.66)	(27.99)
Sigma	9.701***	25.26***	49.30***	79.72***	111.6***	138.3***
	(0.331)	(0.812)	(1.554)	(2.512)	(3.567)	(4.377)
Observations	1,575	1,575	1,575	1,575	1,575	1,575

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

Table 8 Panel 4: Tobit Regressions of Log (Two-Year Patents' N-Year Citations) on Log (Capitalized DC) & Log (Expensed R&D)

	Two-Year Patents' N-year Citations					
VARIABLES	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.0923**	**0.184**	**0.391**	**0.377**	**0.495**	**0.544**
	(0.0682)	**(0.176)**	**(0.360)**	**(0.584)**	**(0.826)**	**(1.010)**
exp_rd	**0.631*** **	**1.883*** **	**3.963*** **	**6.346*** **	**8.924*** **	**10.84*** **
	(0.103)	**(0.253)**	**(0.502)**	**(0.805)**	**(1.135)**	**(1.374)**
total_asset	0.00122***	0.00340***	0.00719***	0.0118***	0.0169***	0.0206***
	(0.0000874)	(0.000245)	(0.000538)	(0.000888)	(0.00129)	(0.00157)
Mtb	0.570*	1.629**	3.661**	6.676***	9.312***	10.78**
	(0.301)	(0.774)	(1.559)	(2.517)	(3.523)	(4.275)
roa_ebit	22.63***	59.04***	107.2***	173.6***	238.0***	291.7***
	(4.266)	(9.958)	(18.81)	(30.25)	(41.94)	(50.64)
Leverage	0.165	-5.095	-22.23	-42.96	-74.38	-75.57
	(4.444)	(11.34)	(23.21)	(37.52)	(52.98)	(64.29)
current_ratio	1.298***	2.335**	2.592	3.122	3.004	4.215
	(0.403)	(1.006)	(2.063)	(3.348)	(4.712)	(5.645)
annual_return	0.00159	0.0104	0.0143	0.0275	0.0117	-0.000658
	(0.0104)	(0.0268)	(0.0543)	(0.0879)	(0.125)	(0.150)
sigma	17.07***	45.63***	94.50***	153.7***	216.7***	262.5***
	(0.569)	(1.426)	(2.999)	(4.913)	(7.075)	(8.500)
Observations	1,575	1,575	1,575	1,575	1,575	1,575

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

Table 8 Panel 5: Tobit Regression of Log (Three-Year Patents' N-Year Citations) On Log (Capitalized DC) & Log (Expensed R&D)

	Three-Year Patents' N-year Citations					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	0.0567	0.261	0.555	1.112	0.779	0.984
	(0.0560)	(0.168)	(0.347)	(0.977)	(0.595)	(0.847)
exp_rd	0.166***	0.506***	1.025***	2.832***	1.733***	2.444***
	(0.0163)	(0.0480)	(0.0985)	(0.278)	(0.169)	(0.241)
at_conv	0.000293	0.000752	0.00146	0.00485	0.00277	0.00407
	(0.000211)	(0.000616)	(0.00126)	(0.00350)	(0.00214)	(0.00302)
Mtb	0.771*	2.562**	4.649**	13.81**	8.825**	12.36**
	(0.396)	(1.089)	(2.139)	(5.693)	(3.506)	(4.857)
roa_ebit	28.80***	76.35***	134.7***	327.1***	210.9***	286.1***
	(5.159)	(12.30)	(22.47)	(58.08)	(36.31)	(49.85)
Leverage	14.79***	36.09**	59.19*	152.7*	87.69*	110.8
	(5.714)	(15.65)	(30.89)	(84.29)	(51.39)	(71.77)
current_ratio	2.410***	5.896***	9.790***	22.94***	14.80***	19.54***
	(0.493)	(1.296)	(2.526)	(6.776)	(4.154)	(5.742)
annual_return	0.0265**	0.0785**	0.147**	0.332*	0.232**	0.305*
	(0.0130)	(0.0353)	(0.0686)	(0.185)	(0.114)	(0.159)
Constant	-19.62***	-43.97***	-66.97***	-146.2**	-112.1***	-137.6***
	(4.423)	(11.78)	(22.26)	(59.48)	(37.25)	(50.90)
Sigma	21.52***	60.43***	120.4***	326.3***	200.4***	278.9***
	(0.728)	(2.033)	(4.092)	(11.28)	(6.970)	(9.872)
Observations	1,575	1,575	1,575	1,575	1,575	1,575
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1						

Table 8 Panel 2 shows the mean and median effect for the Tobit models in Table 8 Panel 1. Comparing with OLS model's regressions in Table 6 Panel 1, both median and mean effect of capitalized R&D and expenses are 800% or more of the estimates from the original OLS regressions. The average effect of capitalized DC's impact on the total patent counts is 82% of the expensed R&D. However, the median effect shows that capitalized DC's impact is 155% or more of the expensed R&D.

I also run the Tobit model using n years (1-3 years) patents' n years (1-6 years) citations as the dependent variable. The results are in Table 8 Panel 3 to Table 8 Panel 5. The estimated coefficients of the capitalized DC are positive but statistically insignificant. The estimated coefficients of the expensed R&D are positive and statistically significant at 1% significance level. The difference between the expensed R&D estimated coefficients and the capitalized ones are statistically insignificant using F tests.

Besides large numbers of zeros in the dependent variables, patent counts and patent citations, my sample has large number of zeros in the independent variables, capitalized DC and expensed R&D. As a sensitivity test, I exclude those observations with zeros capitalized DC and zero expensed R&D and rerun OLS model using Equation 1 and Equation 2. The results are shown in Table 9. Panel 1 to Panel 6.

Table 9: OLS Regressions with Sample Eliminating Zero Dependent and Independent Variables

Table 9 Panel 1: Eliminating Zeroes. Regress 'Log of Patent Counts' On 'Capitalized DC' And 'Expensed R&D'

	Patent Counts					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.0884*** **	**0.0922*** **	**0.0997*** **	**0.105*** **	**0.110*** **	**0.107*** **
	(0.0266)	**(0.0298)**	**(0.0307)**	**(0.0312)**	**(0.0314)**	**(0.0321)**
exp_rd	**0.411*** **	**0.450*** **	**0.466*** **	**0.505*** **	**0.503*** **	**0.504*** **
	(0.0315)	**(0.0334)**	**(0.0348)**	**(0.0358)**	**(0.0362)**	**(0.0370)**
total_assets	0.0000209**	0.0000104	0.00000995	0.00000687	0.00000526	0.00000541
	(0.00000878)	(0.0000101)	(0.0000104)	(0.0000105)	(0.0000109)	(0.0000112)
Mtb	0.0295	0.0481	0.0495	0.0550	0.0495	0.0484
	(0.0337)	(0.0359)	(0.0362)	(0.0375)	(0.0385)	(0.0391)
roa_ebit	1.491***	1.477***	1.594***	1.730***	1.796***	1.802***
	(0.387)	(0.403)	(0.435)	(0.463)	(0.472)	(0.473)
Leverage	0.436	0.616	0.731*	0.968**	0.969**	0.995**
	(0.403)	(0.426)	(0.440)	(0.440)	(0.446)	(0.448)
current_ratio	-0.0294	-0.0456	-0.0330	0.0148	0.0285	0.0551
	(0.0402)	(0.0418)	(0.0441)	(0.0454)	(0.0462)	(0.0475)
annual_return	0.000242	0.00116	0.00128	0.00160*	0.00182*	0.00196*
	(0.000793)	(0.000850)	(0.000901)	(0.000965)	(0.000985)	(0.00101)
Constant	1.577***	1.847***	1.933***	1.833***	1.981***	2.107***
	(0.321)	(0.340)	(0.346)	(0.343)	(0.348)	(0.350)
Country & Year fixed effect	Y	Y	Y	Y	Y	Y
Observations	791	845	874	915	915	915
R-squared	0.546	0.527	0.522	0.525	0.516	0.507

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

Table 9 Panel 2: Eliminating Zeroes. Regress 'Log of Current-Year Patents' N-Year Citations' On 'Capitalized DC' and 'Expensed R&D'

	Current Year Patents' N-Year Citations					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.195***	**0.380*****	**0.425*****	**0.328*****	**0.294****	**0.338*****
	(0.102)	**(0.112)**	**(0.112)**	**(0.114)**	**(0.116)**	**(0.115)**
exp_rd	**1.238*****	**1.311*****	**1.299*****	**1.298*****	**1.338*****	**1.301*****
	(0.113)	**(0.116)**	**(0.116)**	**(0.118)**	**(0.123)**	**(0.124)**
total_assets	0.0000683**	-0.00000373	-0.0000441*	-0.0000442	-0.0000515*	-0.0000606**
	(0.0000274)	(0.0000262)	(0.0000266)	(0.0000275)	(0.0000280)	(0.0000282)
Mtb	0.0820	0.112	0.221**	0.223*	0.216*	0.185
	(0.110)	(0.113)	(0.112)	(0.114)	(0.117)	(0.118)
roa_ebit	3.120**	6.214***	4.545***	4.743***	3.799**	3.094*
	(1.218)	(1.596)	(1.732)	(1.811)	(1.772)	(1.804)
leverage	2.922**	3.851***	4.887***	5.032***	4.274***	4.382***
	(1.488)	(1.440)	(1.369)	(1.382)	(1.385)	(1.397)
current_ratio	0.217	0.145	0.00814	0.0311	-0.0144	0.00839
	(0.143)	(0.154)	(0.154)	(0.162)	(0.165)	(0.166)
annual_return	0.00276	0.000370	-0.000625	0.00128	0.00210	0.00321
	(0.00302)	(0.00327)	(0.00336)	(0.00343)	(0.00346)	(0.00349)
Constant	-8.468***	-7.140***	-5.820***	-5.219***	-4.899***	-4.716***
	(1.050)	(1.104)	(1.108)	(1.115)	(1.149)	(1.156)
Country & Year fixed effect	Y	Y	Y	Y	Y	Y
Observations	819	842	864	874	878	881
R-squared	0.438	0.453	0.439	0.413	0.401	0.385

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

Table 9 Panel 3: Eliminating Zeroes. Regress 'Log of Two-Years Patents' N Years Citations' on 'Capitalized DC' And 'Expensed R&D'

	Two Years Patents' N-Year Citations					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.235****	**0.398*****	**0.439*****	**0.282*****	**0.303*****	**0.335*****
	(0.120)	**(0.119)**	**(0.111)**	**(0.105)**	**(0.105)**	**(0.101)**
exp_rd	**1.285*****	**1.235*****	**1.154*****	**1.197*****	**1.141*****	**1.062*****
	(0.127)	(0.117)	(0.116)	(0.117)	(0.121)	(0.118)
total_assets	0.0000429*	-0.0000169	-0.0000524**	-0.0000437*	-0.0000462**	-0.0000492**
	(0.0000256)	(0.0000231)	(0.0000227)	(0.0000229)	(0.0000232)	(0.0000227)
mtb	0.184	0.162	0.222**	0.236**	0.227**	0.189*
	(0.119)	(0.117)	(0.112)	(0.111)	(0.110)	(0.110)
roa_ebit	5.353***	6.669***	4.453**	4.135**	4.527**	3.680**
	(1.434)	(1.860)	(1.910)	(1.806)	(1.815)	(1.775)
leverage	4.247***	4.610***	3.850***	4.146***	4.092***	4.439***
	(1.464)	(1.312)	(1.267)	(1.263)	(1.266)	(1.247)
current_ratio	0.170	0.247	0.105	0.127	0.0593	0.0653
	(0.153)	(0.161)	(0.160)	(0.165)	(0.166)	(0.165)
annual_return	0.000447	0.00105	0.00107	0.00183	0.000861	0.00120
	(0.00330)	(0.00336)	(0.00333)	(0.00327)	(0.00331)	(0.00329)
Constant	-7.404***	-6.181***	-4.096***	-4.119***	-3.058***	-2.648**
	(1.097)	(1.112)	(1.077)	(1.094)	(1.119)	(1.093)
Country & Year fixed effect						
Observations	804	852	859	881	883	886
R-squared	0.459	0.428	0.394	0.378	0.359	0.340

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

Table 9 Panel 4: Eliminating Zeroes. Regress 'Log of Three-Year Patents' N Years Citations' On 'Capitalized DC' And 'Expensed R&D'

	Three Years' Patents' N-Year Citations					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.275****	**0.401*****	**0.371*****	**0.248*****	**0.261*****	**0.263*****
	(0.124)	**(0.115)**	**(0.101)**	**(0.0950)**	**(0.0923)**	**(0.0908)**
exp_rd	**1.233*****	**1.151*****	**1.054*****	**1.112*****	**1.038*****	**0.960*****
	(0.133)	**(0.119)**	**(0.116)**	**(0.115)**	**(0.117)**	**(0.111)**
total_assets	0.0000253	-0.0000210	-0.0000427**	-0.0000403*	-0.000039*	-0.0000382*
	(0.0000247)	(0.0000204)	(0.0000204)	(0.0000208)	(0.0000209)	(0.0000205)
mtb	0.267**	0.251**	0.252**	0.235**	0.243**	0.212**
	(0.117)	(0.109)	(0.104)	(0.103)	(0.102)	(0.101)
roa_ebit	5.435***	5.478***	4.006**	3.856**	4.479**	3.425**
	(1.641)	(1.978)	(1.864)	(1.758)	(1.748)	(1.664)
leverage	4.851***	4.073***	3.077**	3.362***	3.467***	3.715***
	(1.409)	(1.250)	(1.195)	(1.184)	(1.182)	(1.139)
current_ratio	0.292*	0.289*	0.102	0.0761	0.00554	-0.0329
	(0.161)	(0.160)	(0.156)	(0.162)	(0.163)	(0.161)
annual_return	0.00102	0.00215	0.00188	0.00250	0.00120	0.000680
	(0.00341)	(0.00320)	(0.00308)	(0.00308)	(0.00305)	(0.00299)
Constant	-7.348***	-5.754***	-3.132***	-3.047***	-1.545	-0.904
	(1.161)	(1.129)	(1.051)	(1.063)	(1.048)	(1.007)
Observations	801	856	867	887	885	890
R-squared	0.445	0.404	0.368	0.362	0.349	0.326

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

Table 9 Panel 5: OLS Model with Sample Eliminating Zeroes: Regress 'Log of Four-Year Patents' N Years Citations' On 'Capitalized DC' And 'Expensed R&D'

	Four Years' Patents' N-Year Citations					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.399*** **	**0.372*** **	**0.325*** **	**0.248*** **	**0.238*** **	**0.241*** **
	(0.124)	**(0.109)**	**(0.0943)**	**(0.0889)**	**(0.0866)**	**(0.0854)**
exp_rd	**1.153*** **	**1.131*** **	**0.998*** **	**1.065*** **	**0.985*** **	**0.915*** **
	(0.131)	**(0.117)**	**(0.112)**	**(0.112)**	**(0.111)**	**(0.104)**
	-		-	-		
total_assets	0.000000294	-0.0000303	0.0000425**	0.0000437**	-0.0000376*	-0.0000372*
	(0.0000248)	(0.00001.99)	(0.00002.02)	(0.0000205)	(0.0000207)	(0.0000201)
mtb	0.266**	0.251**	0.222**	0.207**	0.206**	0.176*
	(0.120)	(0.109)	(0.101)	(0.0998)	(0.1000)	(0.101)
roa_ebit	5.808***	4.757**	3.202*	3.306**	3.944**	2.707*
	(1.757)	(1.922)	(1.674)	(1.641)	(1.639)	(1.565)
leverage	4.526***	3.391***	2.718**	2.869**	2.851**	2.924***
	(1.394)	(1.219)	(1.166)	(1.168)	(1.157)	(1.116)
current_ratio	0.257	0.265*	0.0643	0.0840	0.00904	-0.0399
	(0.163)	(0.160)	(0.157)	(0.162)	(0.162)	(0.161)
annual_return	0.00208	0.00234	0.00322	0.00397	0.00212	0.00143
	(0.00351)	(0.00316)	(0.00298)	(0.00298)	(0.00294)	(0.00285)
Constant	-6.740***	-5.083***	-2.690**	-2.704**	-0.941	-0.304
	(1.192)	(1.116)	(1.053)	(1.055)	(1.025)	(0.967)
Observations	803	857	874	891	888	895
R-squared	0.431	0.389	0.347	0.345	0.333	0.311

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

Table 9 Panel 6: OLS Regressions with Sample Eliminating Zeroes: Regress 'Log of Five-Year Patents' N Years Citations' On 'Capitalized DC' And 'Expensed R&D'

	Five Years' Patents' N-Year Citations					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	**0.437*** **	**0.331*** **	**0.288*** **	**0.206** **	**0.173** **	**0.191** **
	(0.121)	**(0.101)**	**(0.0890)**	**(0.0838)**	**(0.0789)**	**(0.0766)**
exp_rd	**1.138*** **	**1.103*** **	**0.922*** **	**0.987*** **	**0.884*** **	**0.812*** **
	(0.129)	(0.115)	(0.108)	(0.108)	(0.104)	(0.0971)
total_assets	-0.0000138	-0.0000336	-0.0000355*	-0.0000354*	-0.0000243	-0.0000249
	(0.0000245)	(0.00002)	(0.0000201)	(0.0000202)	(0.0000201)	(0.0000195)
mtb	0.249**	0.217**	0.194*	0.205**	0.183*	0.161
	(0.121)	(0.109)	(0.101)	(0.0998)	(0.0991)	(0.0998)
roa_ebit	4.563**	4.531**	3.343**	3.611**	4.235***	3.157**
	(1.880)	(1.844)	(1.628)	(1.607)	(1.591)	(1.510)
leverage	3.991***	2.520**	2.441**	2.596**	2.544**	2.511**
	(1.355)	(1.208)	(1.145)	(1.146)	(1.120)	(1.066)
current_ratio	0.236	0.220	0.0309	0.0579	-0.0231	-0.0571
	(0.165)	(0.162)	(0.158)	(0.161)	(0.159)	(0.156)
annual_return	0.00438	0.00225	0.00393	0.00421	0.00287	0.00271
	(0.00348)	(0.00313)	(0.00285)	(0.00287)	(0.00276)	(0.00270)
Constant	-6.434***	-4.367***	-2.263**	-2.164**	-0.165	0.286
	(1.192)	(1.105)	(1.050)	(1.061)	(1.002)	(0.927)
Observations	803	863	876	891	888	894
R-squared	0.422	0.373	0.329	0.327	0.314	0.297

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

Table 10 summarizes non-zero independent variables' regression results in Table 9 Panel 1 to Table 9 Panel 6. The result is robust and consistent with my hypothesis. The regression results of the non-zero subsample are consistent with the main regression results in Tables 4 and 5. The estimated coefficients on both capitalized development costs and expensed R&D are positive and statistically significant at 1% significance level. The mean and median effect of my non-zero sample are even stronger for both capitalized R&D and expensed R&D on firms' innovation than the whole sample. For example, according to median effect, 1-million-euro investment in the capitalized DC will lead to 13% increase in patents counts in one-year and 1 million-euro investment in the expensed R&D will lead to 7% increase in patent counts in one year.

Table 10: Summary of Table 9 -OLS Regressions with Sample Eliminating Zeroes Variables

		Log (N Years' Patent Counts)					
		1 y	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Capitalized DC	Mean effect	1.0073	1.0506	1.1361	1.1964	1.2534	1.2192
Expensed R&D		1.0276	1.1251	1.1651	1.2626	1.2576	1.2601
Capitalized DC	Median effect	13.2932	13.8647	14.9925	15.7895	16.5414	16.0902
Expensed R&D		7.1329	7.8098	8.0875	8.7643	8.7296	8.7470
Capitalized DC/Expensed R&D	Mean effect	0.9803	0.9338	0.9751	0.9476	0.9967	0.9676
	Median effect	1.8636	1.7753	1.8538	1.8016	1.8949	1.8395

		Log of (Current Years' Patents with N-Year Citations)					
		1Y citations	**2Y citations**	**3Y citations**	**4Y citations**	**5Y citations**	**6Y citations**
Capitalized DC	Mean effect	2.2220	4.3300	4.8428	3.7375	3.3500	3.8514
Expensed R&D		3.0952	3.2777	3.2477	3.2452	3.3452	3.2527
Capitalized DC	Median effect	29.3233	57.1429	63.9098	49.3233	44.2105	50.8271
Expensed R&D		21.4856	22.7525	22.5443	22.5269	23.2211	22.5790
Capitalized DC/Expensed R&D	Mean effect	0.7179	1.3211	1.4912	1.1517	1.0015	1.1841
	Median effect	1.3648	2.5115	2.8349	2.1895	1.9039	2.2511

		Log of (2 Years' Patents with N-Year Citations)					
		1Y citations	**2Y citations**	**3Y citations**	**4Y citations**	**5Y citations**	**6Y citations**
Capitalized DC	Mean effect	**2.6778**	**4.5351**	**5.0023**	**3.2133**	**3.4526**	**3.8172**
Expensed R&D		**3.2127**	**3.0877**	**2.8851**	**2.9927**	**2.8526**	**2.6551**
Capitalized DC	Median effect	35.3384	59.8496	66.0150	42.4060	45.5639	50.3759
Expensed R&D		22.3013	21.4335	20.0278	20.7740	19.8022	18.4311
Capitalized DC/Expensed R&D	Mean effect	0.8335	1.4688	1.7338	1.0737	1.2103	1.4377
	Median effect	1.5846	2.7923	3.2962	2.0413	2.3010	2.7332

		Log of (3 Years' Patents with N-Year Citations)					
		1Y citations	**2Y citations**	**3Y citations**	**4Y citations**	**5Y citations**	**6Y citations**
Capitalized DC	Mean effect	**3.1335**	**4.5693**	**4.2274**	**2.8259**	**2.9740**	**2.9968**
Expensed R&D		**3.0827**	**2.8776**	**2.6351**	**2.7801**	**2.5951**	**2.4001**
Capitalized DC	Median effect	41.3534	60.3008	55.7895	37.2932	39.2481	39.5489
Expensed R&D		21.3988	19.9757	18.2923	19.2989	18.0146	16.6609
Capitalized DC/Expensed R&D	Mean effect	1.0165	1.5879	1.6043	1.0165	1.1460	1.2486
	Median effect	1.9325	3.0187	3.0499	1.9324	2.1787	2.3738

Log of (4 Years' Patents with N-Year Citations)

		1Y citations	2Y citations	3Y citations	4Y citations	5Y citations	6Y citations
Capitalized DC	Mean effect	**4.5465**	**4.2388**	**3.7033**	**2.8259**	**2.7119**	**2.7461**
Expensed R&D		**2.8826**	**2.8276**	**2.4951**	**2.6626**	**2.4626**	**2.2876**
Capitalized DC	Median effect	60.0000	55.9399	48.8722	37.2932	35.7895	36.2406
Expensed R&D		20.0104	19.6286	17.3204	18.4832	17.0948	15.8799
Capitalized DC/Expensed R&D	Mean effect	1.5772	1.4991	1.4842	1.0613	1.1012	1.2004
	Median effect	2.9984	2.8499	2.8217	2.0177	2.0936	2.2822

		Log of (5 Years' Patents with N-Year Citations)					
		1Y citations	**2Y citations**	**3Y citations**	**4Y citations**	**5Y citations**	**6Y citations**
Capitalized DC	Mean effect	**4.9795**	**3.7717**	**3.2817**	**2.3473**	**1.9713**	**2.1764**
Expensed R&D		**2.8451**	**2.7576**	**2.3051**	**2.4676**	**2.2101**	**2.0301**
Capitalized DC	Median effect	65.7143	49.7744	43.3083	30.9774	26.0150	28.7218
Expensed R&D		19.7501	19.1427	16.0014	17.1295	15.3419	14.0923
Capitalized DC/Expensed R&D	Mean effect	1.7502	1.3677	1.4237	0.9512	0.8919	1.0721
	Median effect	3.3273	2.6002	2.7065	1.8084	1.6957	2.0381

My research design regresses the determinant variables, patent counts and patent citations, which extend over multiple years on the current year's capitalized DC and expensed R&D. To control for the previous R&D costs' impact on my regressions, I include past years R&D as control variables in my regressions as a sensitivity test. I include lagged one year, lagged two years' and lagged three years' capitalized DC and expensed R&D into my non-zero R&D regressions. The regression results with lagged variables are shown in Table 11. The estimated coefficients of capitalized DC and expensed R&D are positive and statistically significant at 1% significant level while the lagged variables are insignificant. Table 12 summarize the median and mean effect of the regressions in Table 11. According to the mean effect, the one-year patent counts' regression shows that capitalized DC's impact on patent counts is 107% of patent citations. However, the regressions with the dependent variables of the two years to six years patent counts shows opposite results where capitalized DC's impact on patent counts is smaller than the expensed R&D's impact on patent citations (66% to 89%).

As another sensitivity test to control for past years' R&D costs' impact on firms' innovation, I replace the independent variables: current year's capitalized DC and expensed R&D, with the firms' three years cumulative capitalized DC and expensed R&D. The regression results are presented in Table 13.

Table 11: OLS Model Including Lagged R&D Variables with Sample Eliminating Zeroes

Regress 'log of patent counts' on 'capitalized DC' and 'expensed R&D'

	Patent Counts					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	0.129***	0.123***	0.106**	0.0971**	0.0919*	0.0841
	(0.0396)	(0.0455)	(0.0490)	(0.0492)	(0.0506)	(0.0524)
exp_rd	0.387***	0.444***	0.425***	0.418***	0.412***	0.410***
	(0.0776)	(0.0647)	(0.0599)	(0.0605)	(0.0616)	(0.0629)
cap_dc _1y_prior	-0.00797	-0.0186	-0.00231	-0.00413	-0.000321	0.00343
	(0.0158)	(0.0194)	(0.0217)	(0.0216)	(0.0222)	(0.0226)
exp_rd _1y_prior	0.0376	-0.0177	0.00823	0.00235	0.00743	0.00750
	(0.0834)	(0.0578)	(0.0491)	(0.0473)	(0.0447)	(0.0428)
cap_dc _2y_prior	-0.0157	0.00925	-0.00647	-0.00207	-0.000281	-9.82e-05
	(0.0164)	(0.0190)	(0.0191)	(0.0195)	(0.0201)	(0.0204)
exp_rd _2y_prior	-0.00657	0.0164	0.00922	0.0157	0.0193	0.0212
	(0.0495)	(0.0395)	(0.0413)	(0.0423)	(0.0423)	(0.0423)
cap_dc _3y_prior	0.00241	-0.00614	0.0107	0.00738	0.00870	0.0106
	(0.0141)	(0.0150)	(0.0153)	(0.0156)	(0.0161)	(0.0162)
exp_rd _3y_prior	0.0150	0.0150	0.0271	0.0306	0.0333	0.0364
	(0.0251)	(0.0276)	(0.0296)	(0.0305)	(0.0309)	(0.0309)
total_assets	2.06e-05*	1.53e-05	1.21e-05	1.29e-05	1.14e-05	1.17e-05
	(1.08e-05)	(1.20e-05)	(1.26e-05)	(1.32e-05)	(1.38e-05)	(1.42e-05)
mtb	0.0385	0.0637	0.0575	0.0518	0.0332	0.0204
	(0.0535)	(0.0548)	(0.0562)	(0.0562)	(0.0576)	(0.0589)
roa_ebit	0.961*	1.126**	1.196**	1.843***	1.882***	1.846***
	(0.581)	(0.552)	(0.591)	(0.630)	(0.632)	(0.635)
leverage	-0.0227	0.0938	0.362	0.450	0.495	0.543
	(0.553)	(0.583)	(0.582)	(0.591)	(0.606)	(0.621)
current_ratio	0.00643	-0.0117	0.00547	0.0172	0.0507	0.0865

	(0.0575)	(0.0597)	(0.0636)	(0.0661)	(0.0683)	(0.0698)
annual_return	0.000825	0.00154	0.00179*	0.00192*	0.00221*	0.00253**
	(0.000988)	(0.000977)	(0.00103)	(0.00109)	(0.00114)	(0.00116)
Constant	1.361***	1.846***	2.021***	2.356***	2.504***	2.600***
	(0.357)	(0.357)	(0.371)	(0.373)	(0.390)	(0.405)
Country and year fixed effect	Y	Y	Y	Y	Y	Y
Observations	474	509	525	535	535	535
R-squared	0.555	0.548	0.549	0.533	0.523	0.517

Table 12: Summary of Table 11-Lagged R&D Variables are Included

1 million R&D investment's impact on the firms' patent counts

		Patent Counts					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
cap_dc	Mean effect	0.62%	0.59%	0.51%	0.47%	0.44%	0.41%
	Median effect	-0.12%	3.41%	2.94%	2.69%	2.55%	2.33%
exp_rd	Mean effect	0.58%	0.66%	0.63%	0.62%	0.61%	0.61%
	Median effect	-0.01%	3.51%	3.36%	3.30%	3.26%	3.24%
cap_dr/exp_rd	Mean effect	107.97%	89.73%	80.79%	75.24%	72.25%	66.44%
	Median effect	973.65%	97.26%	87.56%	81.55%	78.31%	72.01%

Table 13: OLS Model with Three Years R&D Variables
(Sample Eliminating Zeroes)
Regress 'Log of Patent Counts' On 'Capitalized DC' And 'Expensed R&D'

	N-years' Patent Counts					
	1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
three years cap_dc	**0.0907*** **	**0.106*** **	**0.120*** **	**0.107*** **	**0.106*** **	**0.112*** **
	(0.0325)	**(0.0336)**	**(0.0330)**	**(0.0333)**	**(0.0341)**	**(0.0354)**
three years exp_rd	**0.432*** **	**0.459*** **	**0.466*** **	**0.488*** **	**0.489*** **	**0.496*** **
	(0.0356)	**(0.0387)**	**(0.0389)**	**(0.0402)**	**(0.0410)**	**(0.0422)**
total assets	1.45e-05	9.40e-06	5.63e-06	4.33e-06	2.80e-06	1.57e-06
	(9.92e-06)	(1.07e-05)	(1.12e-05)	(1.16e-05)	(1.21e-05)	(1.25e-05)
mtb	0.0386	0.0584	0.0525	0.0489	0.0341	0.0261
	(0.0423)	(0.0438)	(0.0443)	(0.0455)	(0.0466)	(0.0478)
roa_ebit	1.430***	1.452***	1.566***	1.984***	2.046***	2.004***
	(0.486)	(0.476)	(0.516)	(0.545)	(0.556)	(0.559)
leverage	0.133	0.289	0.484	0.657	0.662	0.676
	(0.482)	(0.504)	(0.507)	(0.513)	(0.516)	(0.526)
current_ratio	-0.0213	-0.0320	-0.0211	0.00531	0.0275	0.0685
	(0.0506)	(0.0518)	(0.0535)	(0.0555)	(0.0564)	(0.0586)
annual_return	0.000459	0.00109	0.00135	0.00162	0.00173	0.00198*
	(0.000910)	(0.000942)	(0.000973)	(0.00102)	(0.00106)	(0.00109)
Constant	0.923***	1.141***	1.318***	1.440***	1.680***	1.729***
	(0.349)	(0.369)	(0.365)	(0.370)	(0.365)	(0.376)
Year country fixed effect	Y	Y	Y	Y	Y	Y
Observations	583	625	646	664	664	664
R-squared	0.558	0.552	0.551	0.540	0.530	0.522

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

Both independent variables: three years cumulative capitalized DC and three years cumulative expensed R&D are positive and statistically significant at 1% significance level. Table 14 summarizes the median and mean effects of Table 13's regressions. On contrary to my main findings, the three years cumulative capitalized DC's impact on patent counts is only 68% to 90% of the expensed R&D's. It shows that in long-term, the less matured R&D: expensed R&D can become mature and is also a vital part of the firms' R&D investments.

The previous R&D capitalization research in IFRS study firms' R&D using firms' financial performance measures and find mixed result. Here I follow the previous literature using future sales as the dependent variable and rerun Equation (1) and Equation (2). The regression result show that the both capitalized DC and expensed R&D have a positive and statistically significant estimated coefficients. Thus, both capitalized Dc and expensed R&D are positively correlated with firms' future sales. However, the mean and median effect show that capitalized DC have smaller impact on firms' future sales than the expensed R&D (68% to 85%) which is on the contrary of my main findings. One of the explanations is that the future sales, as a financial performance measures, contain other noises when measuring firms R&D performance. This could explain why we did not find a relationship that we expected. That is another reason why I use the innovation as firms' R&D performance measures.

Table 14: Summary of Table 13-OLS Model with Three Years R&D Variables (Sample Eliminating Zeroes)
1 Million R&D Investment's Impact on The Firms' Patent Counts

		Patent Counts					
		1 year	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
three years cap_dc	Mean	0.44%	0.51%	0.58%	0.52%	0.51%	0.54%
	median	2.52%	2.94%	3.33%	2.97%	2.94%	3.11%
three years exp_rd	Mean	0.64%	0.68%	0.70%	0.73%	0.73%	0.74%
	median	3.41%	3.63%	3.68%	3.86%	3.86%	3.92%
three years cap_dc/	Mean	68.01%	74.80%	83.41%	71.02%	70.21%	73.14%
three years exp_rd	median	73.71%	81.08%	90.41%	76.98%	76.10%	79.28%

Table 15. R&D Capitalization and Firms' Future Sales with OLS Regression

	Firms' Future Sales		
VARIABLES	**1 year**	**2 years**	**3 years**
cap_dc	**0.106*****	**0.103*****	**0.0943*****
	(0.0186)	**(0.0191)**	**(0.0203)**
exp_rd	**0.509*****	**0.517*****	**0.528*****
	(0.0188)	**(0.0195)**	**(0.0204)**
total_assets	0.0000846***	0.0000831***	0.0000822***
	(0.00000365)	(0.00000374)	(0.00000407)
mtb	-0.0728***	-0.0794***	-0.0856***
	(0.0179)	(0.0196)	(0.0207)
roa_ebit	3.174***	3.202***	3.254***
	(0.282)	(0.280)	(0.298)
leverage	1.040***	1.145***	1.223***
	(0.232)	(0.231)	(0.234)
current_ratio	-0.296***	-0.272***	-0.241***
	(0.0263)	(0.0276)	(0.0284)
annual_return	0.00121**	0.00170***	0.00191***
	(0.000513)	(0.000534)	(0.000557)
Constant	4.380***	4.252***	4.121***
	(0.191)	(0.203)	(0.216)
Country and year fixed effect.	Y	Y	Y
Observations	896	873	848
R-squared	0.887	0.887	0.883
Robust standard errors in parentheses			

Table 16: Summary of Table 15

OLS Regression with Firms' Future Sales as the Dependent Variable

		Firms' Future N-Year Sales		
VARIABLES		**1 year**	**2 years**	**3 years**
cap_dc	mean effect	0.74%	0.72%	0.65%
	median effect	3.43%	3.33%	3.05%
exp_rd	mean effect	0.92%	0.94%	0.96%
	median effect	4.02%	4.08%	4.17%
cap_dc/exp_rd	mean effect	79.72%	76.27%	68.37%
	median effect	85.28%	81.58%	73.13%

CHAPTER 7

CONCLUSION

This paper examines the R&D spending and firms' innovation using a unique hand-collected high-tech EU country sample 2005-2018 with 1575 firm year observations. I proxied innovation using patent counts and patent citations. I find that both capitalized development cost and expensed R&D cost positively impact the firms' innovation as both R&D variables are positively associated with firms' patent counts and patent citations. Moreover, capitalized development costs have a more significant impact on innovation than the expensed ones and the difference is statistically significant at 1% significance level. In median effect, firms' capitalized DC's impact on future patent counts and patent citations usually are 200% or more of the expensed R&D's impact. It shows that there is fundamental difference between firms' capitalized DC and expensed R&D. This paper provides additional support of IFRS R&D capitalization and the necessity of separating capitalized development costs from the expensed R&D costs in the financial statements.

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APPENDICES

A. HIGH TECH INDUSTRIES WITH FOUR DIGIT SIC CODES

IND	IDS	Old (S-L)	IDS, SIC Description	SIC Codes
Industry (Quasi 2-digit)	IDS			
14 Computers & comp. equip.	116	116	Electronic computing equipment	3570-3573 3575 3576 3577
14 Computers & comp. equip.	117	--	Calculating machines excl. comp.	3578
15 Electrical machinery	119	119	Refrigerating & heating equip. (comml)	3580-3582 3585 3589 3596
15 Electrical machinery	120	120	Power distribution & transformers	3612
15 Electrical machinery	121	121	Switchgear & switchboard apparatus	3613
15 Electrical machinery	122	122	Motors, generators & industrial controls	3600 3620 3621 3622 3625
15 Electrical machinery	124	--	Electronic & electric coils & connectors	3524 3677
15 Electrical machinery	126	126	Household refrigerators & freezers	3630 3631 3632 3633 3635 3639

15 Electrical machinery	128	128	Lighting fixtures & equipment	3640 3641 36425 3646 3647 3648
15 Electrical machinery	134	134	Primary & storage batteries	3691 3692 3693
15 Electrical machinery	135	135	Engine elctrical equipment & misc	3694 3699
15 Electrical machinery	137	--	Electronic & electric connections	3643 3644 3678
16 Electronic inst. & comm. eq.	125	--	Electronic signaling & alarm systems	3669
16 Electronic inst. & comm. eq.	127	--	Radio & TV broadcasting sets	3663
16 Electronic inst. & comm. eq.	129	129	Radio & TV receiving sets	3651
16 Electronic inst. & comm. eq.	130	130	Records, magnetic, &optical recording	3652 3690 3695
16 Electronic inst. & comm. eq.	131	--	Communication equipment	3661 3662 3669 4810 4812 4813
16 Electronic inst. & comm. eq.	132	132	Electron tubes	3671
16 Electronic inst. & comm. eq.	133	133	Semiconductors & printed circuit boards	3672 3674 3675 3676
16 Electronic inst. & comm. eq.	138	--	Electronic components, computer acc.	3670 3679

16 Electronic inst. & comm. eq.	147	147	Engineering scientific instruments	381x
16 Electronic inst. & comm. eq.	148	148	Measuring & controlling devices	382x
17 Transportation equipment	141	141, 142	Aircraft parts & engines	3720 3721 3724 3728
17 Transportation equipment	143	143	Ship & boat building & repairing	373x 3795
17 Transportation equipment	144	144	Railroad equipment	374x
17 Transportation equipment	145	145	Complete guided missiles, aerospace	376x
19 Optical & medical instruments	149	149	Optical instruments & lenses	3827
19 Optical & medical instruments	150	150	Dental equipment & supplies	3843
19 Optical & medical instruments	151	151	Surg. & med. inst., appliances, & supplies	3840 3841 3842
19 Optical & medical instruments	152	--	X-ray apparatus	3844
19 Optical & medical instruments	153	153	Photographic equipment & supplies	3861
19 Optical & medical instruments	154	-	Electromedical apparatus	3845

20 Pharmaceuticals	45	45	Pharmaceuticals	283x
20 Pharmaceuticals	155	--	Opthalmic goods	3851
IND: Corresponds roughly to the old ARDSIC (Bound et al) but with soap and auto parts broken out for Chandler's segments.				
IDS: Hall-Vopel industries, based on the old Scherer-Levin classification (used in Levin-Reiss and Yale survey stuff). IDS (old) : correspondence to Scherer-Levin)				
SIC: 4-digit sic, using 1987 codes, but roughly corresponding to those in use by Compustat, although not all will be populated.				

Source: Hall, B. H., & Vopel, K. (1997). Innovation, Market Share, and Market Value**.**

B. COMPARISON OF MY HAND COLLECTED R&D SAMPLE WITH THE ESTIMATED DEVELOPMENT COSTS

(1) Estimated DC Cost Sample Size VS Hand Collected Sample Size

	# of obs of Estimated DC cost	My hand collected sample
Observations (for Estimated DC cost sample, if current year and last year's gross development cost assets available)	447	1622
delete negative estimates of Estimated current year development costs	-105	
Final Sample =	342	1622

(2) Compare the Estimated DC Costs with the Actual Number From The Financial Statement

Absolute value of the difference between estimated DC and actual value from the financial statement as a percentage of the actual value

$\frac{\lvert estimate\ DC - actual\ DC \rvert}{actual\ DC}$	# of obs of Estimated DC	% of total estimated sample
<1%	91	26.61%
<5%	124	36.26%
<10%	150	43.86%
<20%	185	54.09%
<50%	252	73.68%

I have hand-collected 1,662 total observations with available capitalized DC and expensed R&D costs information of high-tech firms in EU from 2005 to 2012 based on Compustat Global. The estimated DC is calculated as the current year gross DC assets minus the previous year's gross DC assets. Using the same high-tech firm and year list, I obtain the estimated development costs (DC) from DataStream matched by Sedol number. First, I require a firm to have the current year and previous year's gross capitalized DC. This step returns 447 observations, among which 105 observations' development costs are negative. Thus, my final estimated DC sample consists of only 342 observations compared to my hand-collected sample of 1662. In the next step, I compare the estimating accuracy which is listed in the last section of Appendix B. Out of the estimated 342 development costs (DC), 27% or 91 out of 342 estimated DC have a smaller than 1% difference with the actual DC, while the remaining 73% have higher than 1%. 36% or 124 out of 342 estimated DC have a smaller than 5% difference with the actual ones, while the remaining 64% have higher than 5% difference than the actual ones. 54% or 185 out of 342 have a smaller than 20% difference than the actual DC while 46% or 157 estimated DC have higher than 20% error. There are 26% or 90 estimated DC have higher than 50% error comparing to the actual result. Thus, the comparing to my own original sample, estimated sample has limited data availability and has a large error in its estimation. Therefore, analysis based on the estimated DC is not valid due to the significant errors in the estimation process. Thus, my paper avoid concerns about data validity because I use a hand-collected dataset for current year capitalized DC and expensed R&D