Do patents provide value-relevant information for investors?

A study that examines the value relevance of patents related to standard setting organizations

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Author: T.J.D. Schuite
Student number: 362617

Supervisor: T. Keusch
First Reader: P.Y.E. Leung

Abstract

Firms are restricted to report according to two leading accounting standards: US GAAP and the International Financial Reporting Standards (IFRS). The two accounting standards differ significantly from each other regarding the accounting of R&D of a firm. The US GAAP standard mandates firms to record all their internal R&D outlays as expenditures, while under the IFRS system it is allowed to capitalize the development costs of a firm. This thesis addresses the concerns of value-relevance information of R&D outlays. This thesis looks at value-relevance of the output of R&D investments, namely patents and distinguishes between patents that are related to standard-setting organizations and patents that are unrelated to standard-setting organizations. Standard setting organizations are industry groups that set common standards to meet the needs of the business and society and standard-setting organizations develop standards in order to create new technologies and products. Patent owners can relate their patents to specific standards, because these patents are declared to be essential for developing standards. Besides that, firms could have patents that are not covered in the standard but are relevant for a standard, which are standard-related patents. This thesis evaluates if standard-related patents and standard-essential patent contain valuable information for investors. I find that patents that are related to standard setting organizations contains value-relevant information for investors and could help to value high-intensive R&D firms in a better way. Investors make better predictions of the future prospects of new technologies and products if firms disclose detailed patent information.

Keywords: value-relevance information, R&D, patents, standard-setting organizations, and firm performance.

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1. Introduction

In order to grow as a business, firms need to distinguish themselves from other firms in the market. One way to do this is by creating new products or technologies. Research and Development create the opportunity to discover new products and/or technologies. However, Research and Development is a significant investment for a firm and involves large amounts of expenditures. Market participants use the accounting earnings to value the current R&D expenditures of a firm in order to determine the realized benefits and future benefits of the R&D investments (Sougiannis, 1994). Research shows that reported earnings reflect realized benefits from R&D (Sougiannis, 1994)[1]. Moreover, R&D expenditures in a given year reflect an increase in the net income over a period of seven years and have a positive effect on market value of a company (Sougiannis, 1994). This suggests that R&D expenditures reveal some value-relevant information about the future performance of a company. This is especially important for high intensive R&D firms, where the benefits of the R&D investments can be observed during several years after the investment. However, firms are restricted to report according to two leading accounting standards: US GAAP and the International Financial Reporting Standards (IFRS). The two accounting standards differ significantly from each other regarding the accounting of R&D of a firm. The US GAAP standard mandates firms to record all their internal R&D outlays as expenditures, while under the IFRS system it is allowed to capitalize the development costs of a firm. However, research shows that the capitalization of the development costs generate a substantial amount of value-relevant information (Chen, Gavious and Lev, 2015). This creates opportunities for firms that report their financial statements according to the IFRS standards, because firms could choose to voluntarily disclose the capitalization of development costs to investors. This suggests that firms that report under the IFRS system could better signal information to their investors than firms under the US GAAP system.

This thesis continues to address the concerns of value-relevance information of R&D outlays. However, this thesis looks at value-relevance of the output of R&D investments. To profit from R&D investments, firms could protect themselves through intellectual property rights. Intellectual property rights are temporary rights that give firms the possibility to benefit from the new knowledge and provide firms the possibility to invest in research and development.

[1] The earnings that are used are the earnings before extraordinary items and before advertising and R&D expenditures.

Besides that, it creates a temporary monopoly position, so that potential users have to pay for it (licensing) or cannot get access to the required knowledge (Blind and Thumm, 2004).

This thesis looks only at one specific intellectual property right, namely the patent-protected intellectual property of a firm. A patent gives a firm an exclusive right for a limited period of time for detailed public disclosure of an invention. Patents are the output measure of R&D investments and therefore a good measure to determine whether the output of R&D expenditures provide value-relevance information for investors. The research question of this thesis is as follows:

RQ: Do patents provide value-relevant information for investors?

This thesis looks at the effect of patents on the firm's performance to test whether patents contain value-relevant information. Previous studies show mixed results between the patents and the firm's performance. Research shows that patents have a positive effect on the market value of a company (Hall and Macgravie, 2010; Austin, 1995; Cho and Pucik, 2005). Furthermore, patents grants have a positive relationship with the sales of a company (Scherer, 1965; Comanor and Scherer, 1969). The main reason for this is that licensing patents has a positive effect on the firm's revenues through royalty fees or through market income (e.g., promoting their preferred technology) (Arora and Fosfuri, 2003). However, others find a negative relationship between patents and both return on assets and sales growth of a firm (Artz et al., 2010). Reasons for this are the intent for patenting by firms to play a strategic role in firm's competitiveness (e.g., blocking a competitor's innovation efforts) (Macdonald, 2004). Hence, firms need patents from other firms to create new products and technologies.

Firms could either pay high licensing fees to the other firms or could be part of standard setting organizations to obtain the knowledge of patents from other firms. Standard setting organizations are industry groups that set common standards to meet the needs of the business and society (Lemley, 2002). In standard-setting organizations (SSOs) inventors of different technological methods, users of the technology and other stakeholders come together to set methods so that technologies and products are invented for common use (Baron and Pohlmann, 2015). Two examples of standard setting organizations are the Institute of Electrical and Electronics Engineers (IEEE) and the European Telecommunications Standards Institute (ETSI). The IEEE publishes a third of the world's technical literature in electrical engineering, computer science, and electronics and is a leading developer of international standards of telecommunications, information technology, and power-generation products and services (IEEE, 2016).

The ETSI produces globally-applicable standards for Information and Communications Technologies (ICT), including mobile, radio, broadcast and internet technologies (ETSI, 2016). The ETSI facilitates trade, enables economies and efficiencies, achieves interoperability between firms, and enhances consumer protection and confidence for business and society (ETSI, 2016). SSOs develop standards to create products and new technologies. Examples of standards of the IEEE are the Ethernet, Wi-Fi, Fire wire, and Bluetooth standards (Bekkers and Updegrove, 2012). The ETSI created standards to develop the Global system of Mobile (GSM), smart cards, and digital enhanced cordless telecommunications (DECT) (ETSI, 2016). Patent owners can relate their patents to specific standards, because these patents are declared to be essential for developing standards (Baron and Pohlmann, 2015). Moreover, members of standards are often required by standard setting organizations to cross-license their patents that are essential for the implementation of a standard. This means that firms grant rights to other firms to use their patents. Hence, technology standards could reveal complementary information about the patents of a firm and this information may be value-relevant information for investors (Baron and Spulber, 2015). However, the interaction between patents and standards is not only limited to standard essential patents (SEPs). Firms could have patented a technology with the purpose for including it in a standard, but the SSO did not accept the technology to be essential for the standard. Besides that, multiple competing patent technologies could be used to develop new standards, but none of these patents are considered as SEPs (Baron and Pohlmann, 2015). The patents that are not covered in the standard but are relevant for a standard are called standard-related patents. This thesis evaluates the impact of SSO-related patents (i.e., standard-essential patents and standard-related patents) on the firm's performance to determine the value-relevant information for investors. Furthermore, this thesis tests whether SSO-related patents contain more valuable information than SSO-unrelated patents.

Pohlmann, Knut and Neuhasler (2015) find an inverse U-shaped relationship between owning standard-essential patents and their financial performance. Essential patent declarations increase the firm's value up to a certain optimal level and after that the positive effect decreases by declaring more essential patents than the optimal level. This thesis assumes the same relationship between the standard-essential patents and the firm's performance. Furthermore, this thesis expects to find a similar relationship between standard-related patents of a firm and its performance.

Previous research shows that references to previous existing patents could all contain information about the innovations of a firm (Hall, Jaffe and Trajtenberg, 2005). These references are called patent citations. The market value of a firm is positively correlated with the share of self-citations out of total citations to a firm's patents, and this link gets weaker if the size of a firm's patent portfolio increases (Hall, Jaffe and Trajtenberg, 2005). For this reason, this thesis expects an inverse U-shaped relationship between the patent citations and the firm's performance.

In order to answer the research question and the hypotheses, data is collected from the Searle Center database and KPSS patent database provided by the Indiana University. The Searle Center contains information about firms that are part of a SSO and the KPSS database contains patent information of firms that are part of a SSO as well as firms that are not part of a SSO. This thesis only uses the observations from the KPSS database of firms that are not part of a SSO. The financial data for both the SSO firms and non-SSO firms are retrieved from the COMPUSTAT Fundamentals Annual database.

The main findings of the paper are that standard-related patents of firm have an inverse U-shaped relationship with the firm's performance. Citation-weighted patents have a similar impact on the Tobin's Q of a firm in the current period and have a U-shaped relationship with the Tobin's Q in the next period. Another finding in this thesis is the inverse U-shaped relationship between the Tobin's Q of a firm and total number of essential patent declarations to the standard setting organization. Furthermore, this paper also shows that essential patents have higher impact on the Tobin's Q of a firm compared to standard-related patents. Overall, this thesis shows that standard-setting organizations have a positive effect on the firm value of a firm and that patents contain value-relevant information for investors. Investors could make better predictions of the future prospects of new technologies and products if firms disclose detailed patent information.

This thesis contributes to the academic accounting and innovation literature. This thesis shows that voluntary disclosure of patents could provide value-relevant information for investors. This especially counts for firms that report under the US GAAP system, because the reporting of their R&D expenditures do not reveal any information about the future prospects of the development of new technologies and products. This thesis shows that firms should disclose more information about the characteristics of a patent, because it contains valuable information about the future prospects of new products and technologies.

This means that firms should indicate whether a patent is essential for a standard, standard-related or is not related to any standards. Besides that, this thesis suggests that information about participating in standard-setting organizations also reflects information about the firm's performance. Voluntary disclosure of participation in standard-setting organizations gives investors better insights about the strategic plan of a company. Furthermore, patents could be used as indicator for the level of innovation. This thesis shows that patents that are essential to standards indicate that these patents are needed to develop new products and technologies and are therefore a relevant innovation measure. However, firms should balance their patent portfolio in order to give investors better insights about the value-relevance of their patents. This means that firms could also declare too many patents to standards, causing that several patents contributes little to the standard or are not essential to the standard anymore.

The structure of the thesis is as follows. Section two gives insights on the existing literature of R&D outlays and patents. Furthermore, it describes the market valuation of patents and R&D expenditures and relates to existing literature of standard-setting organizations and standard-essential patents. In section three the hypotheses are developed in order to answer the research question. Section four describes the data and explains the research method of the paper. Section five tests the hypotheses and presents the results. Section six discusses the results and concludes.

2. Literature review

2.1 R&D outlays

Accounting for R&D about the mandated disclosure presentation on accounting financial statements is an on-going debate. The US GAAP mandates firms to record their expenses of all internally generated R&D expenditures in the income statement. The reason for this is that there are concerns about the reliability, objectivity and value-relevance of R&D capitalization (PWC, 2015). On the other hand, IFRS requires firms to recognize the R&D expenditures as an intangible asset if certain criteria are met (IFRS, 2010).

Firms should capitalize their development costs if there is the technical feasibility of completing the product/technology under development, there is an intention to complete the development, firms have the ability to use or sell the product, firms could indicate the probable future economic benefits, firms have the availability of adequate technical, financial and other resources to complete the development, and the firms have the ability to measure reliably the expenditure attributable to the development (IFRS, 2010).

Lev and Sougiannis (1996) address the issues of reliability, objectivity, and value-relevance of R&D capitalization. They find that an adjustment in reported earnings and equity value to reflect the capitalization of R&D are strongly associated with the stock prices and return of a company (Lev and Sougiannis, 1996). According to the researchers, these findings suggest that R&D capitalization contains statistically reliable and economically relevant information. Other researches support these findings (Chan, Martin and Kensinger, 1990; Sundaram, John and John, 1996). Furthermore, the capitalization of development costs provides voluntary forward-looking information on the development potential of products/technologies (Chen, Gavious and Lev, 2015). Chen et al. (2015) also find that a disclosure beyond the mandated financial information of R&D expenditures is value-relevant to investors.

2.2 Patents

Firms strive to maximize their profits. A strategy to maximize profits is by capturing competitive advantage from their technology innovations through patents (Graham et al., 2009). Patent applications and patent grants are the most accurate indicators to determine the technological innovation output (Grupp, 1998). An extensive public document is created if a patent is granted. The front page of a patent contains detailed information about the invention, the inventor, the assignee, and the technological antecedents of the invention (Hall, Jaffe and Trajtenberg, 2005). With a patent grant firms create short-term exclusive (monopoly) rights to the use of an invention and therefore the incentive to create new innovations increases (Hall and Macgravie, 2010). However, other researchers state that patents discourage innovation, because most of the patents are from low quality and these patents do not result in new innovations (Barton, 2000; Hunt, 2001; Meurer, 2002). The benefits to patent inventions are the possibility for companies to ask license fees to other companies (Cohen and Lemley, 2001). Moreover, Hill (1992) finds that if firms do not license their patent, a competitor's technology could take a competitive advantage in the market.

Patents give firms also the opportunity to promote their technology (Lichtenthaler, 2011). So, patents provide information about the innovation and its enablement (Hall and Macgravie, 2010).

On the front page of their patent document firms should also indicate if their patents contain citations (Hall, Jaffe and Trajtenberg, 2005). Citations are the references to previous existing patents. Citations serve the legal right to use other patents in order to develop new patents (Jaffe, Trajtenberg and Henderson, 1993). Patent citations contain information about innovation of firms, because citations are used as indicators of major individual patents (Hall, Jaffe and Trajtenberg, 2005). According to Hall and Torrisi (2007), forward citations are informative for value of the firm. Moreover, if patents contain more citations by following up patents, this reveals that the knowledge of those patents contains valuable information for new innovations (Hall, Jaffe and Trajtenberg, 2005). Other researches find that patents with a greater economic value have more citations and have a higher market value (Harhoff et al., 1997; Trajtenberg, 1990). Besides that, citations-weighted patents are more highly correlated with R&D than simple patent counts, which implies that firms invest more effort into patented innovations that leads to more citations (Hall, Jaffe and Trajtenberg, 2005).

Previous studies show mixed results between the relationship of patents and the financial performance of firms. Patents stocks are positively correlated with the Tobin's Q of a firm (Hall & Macgravie, 2010; Cho and Pucik, 2005). Firms without any patents have lower market values than firms with patents (Austin, 1995). Others find that there is a positive relation between the patents granted and the sales of the company (Scherer, 1965; Comanor and Scherer, 1969). However, Artz et al. (2010) find a negative relation between patents and both return on assets and sales growth. A possible explanation for this is that firms filing patent applications to play a strategic role in firm's competitiveness (e.g., blocking a competitor's innovation efforts) (Macdonald, 2004).

2.3 Market valuation

There are several ways in which a firm could be evaluated. The economic value of a firm could be determined either by accounting information or by the market valuation. The accounting information method is backward-looking and the market valuation reflects a forward-looking viewpoint on the value of the firm's future cash flows (Hirschey, Richardson and Scholz, 2001). Investors use accounting information to indicate the future cash flows of a firm and to determine the value of a firm.

However, there is long-term decline in the relevance of financial statement information as information indicator for the market value of a firm (Brown, Lo and Lys, 1999). Although, previous research shows that inventive output is a relevant measure to provide better perceptions of the long-term benefits that could be derived from R&D expenditures (Hirschey, Richardson and Scholz, 2001). The proxy that is used in this thesis to measure the inventive output is the patent counts of a firm. According to previous papers, patent count information has statistically significant effects on the firm's market values (Grilliches, 1990; Connolly and Hirschey, 1988). Furthermore, the quality of the patents is value relevant and the long-term benefits depend on how often a patent is cited and the technology cycle time (Hirschey, Richardson and Scholz, 2001). The technology cycle time (TCT) indicates the speed of the innovation. If the TCT is shorter, then the long-term value created by R&D expenditures diminishes and the value-relevance of R&D expenditures weakens.

Hirshleifer, Hsu and Li (2013) find that patents or citations relative to their R&D expenditures, which is called innovative efficiency, is a strong positive estimator of future returns. Besides that, they find that there exists mispricing in the market for firms with innovative efficiency. The reason for this is that investors do not fully take into account the news about shifts in innovative efficiency, which is driven by technological changes (Hirshleifer, Hsu and Li, 2013). The main reason for predicting the future prospects of new technologies or products incorrectly is because the significance of the news depends on the strategic plan of a firm and the major shifts in the industrial structure that firms face. One example of this is that approved patents are not directly used to create new products due to capital budget constraints or the extent of competition in the market (Hirshleifer, Hsu and Li, 2013). So, investors cannot directly interpret the influence of the patents on the future prospects of the new technologies or products of a company. Barberis and Shleifer (2003) also find that markets are inefficient and that not all the information is incorporated in the market value of a firm. Markets are efficient if all the available information is immediately fully reflected in the stock prices (Fama, 1970). This paper deals with possible inefficiency in the market by measuring the effect of patents on the market value in a current year, but also by measuring the effect of the patents on the market value in next period.

2.4 Standard setting organizations

One unexplored source about the firm's innovation activities is the firm's participation in standard-setting organizations (SSOs).

Standard-setting organizations aim to achieve an agreement between firms in an industry on the specifications of a technology (Pohlmann, Knut, and Neuhausler, 2015; Lyytinen and King, 2006; Markus et., 2006). SSOs develop standards to create products and new technologies. Patent owners can relate their patents to specific standards, because these patents are declared to be essential for developing standards (Baron and Pohlmann, 2015). Standard-setting organisations have adopted policies to achieve agreements between firms. These policies have an influence on the benefits and costs of firms, and large and small firms have different views about the optimal policy in SSO's (Simcoe, Graham and Feldman, 2009). One of these policies is that SSOs oblige the patent holder to license the patented technology under F/RAND terms if firms declare their patents to standards (Layne-Farrar et al., 2007).[2]

Standard-setting organizations could either be formally or informally created. Formal and informal SSOs differ from each other, because they pursue different standardization processes and have different intellectual property rights rules (Baron and Pohlmann, 2013). Moreover, the technology selection is different in the two settings. Formal SSOs select their technologies and products through consensus agreement and informal SSO achieve this by majority voting procedures (Pohlmann, Knut and Neuhausler, 2015). There is also a difference in accessibility between informal and formal SSOs. Formal SSOs are open for all stakeholders and informal standards require a membership fee of firms. These royalty fees restrain new entrants for participating in informal SSOs (Blind and Pohlmann, 2013). Furthermore, the licensing fees for standard-essential patents are restricted by F/RAND terms in formal SSOs, whereas informal SSOs are less restrictive in the agreements of licensing fees (Pohlmann, 2014). This thesis only considers formal standard setting organizations.

Firms could benefit by participating in standard setting organizations for several reasons. First of all, there is the facilitation of new technologies and products through SSOs (Konig, Beimborn and Weitzel, 2006; Peek, 2010). Standard-setting organizations give firms the opportunity to emerge in new markets, but also to grow in existing markets (Blind , 2004). Besides that, users have more confidence and a higher acceptance in the new products and technologies that are developed by firms in standard-setting organizations (Blind, Gauch and Hawkins, 2010).

[2] FRAND terms are "Fair, Reasonable and Non-Discriminatory and these terms have to be approved before becoming a part of a SSO.

Layne-Farrar and Lerner (2011) show that firms join a SSO due to vertical integration and the symmetry between the quality of a firm's patent portfolio and the standards' overall patent contributions. Furthermore, firms could benefit from cooperative R&D when the spill over rate is high (Choi, 1993). This means that firms could benefit from the expertise and knowledge of other firms. Another reason is that entering in SSO's secures firms to benefit from their patents by making cross-licensing agreements (Ganglmair and Tarantino, 2012). In cross-licensing agreements firms grant other firms in a standard the rights to use their patents for licensing fees that are smaller compared to the licensing fees outside the standard-setting organizations. Another reason to declare patents to standards is that firms could be pessimistic about the value of their own patents. Declaring patents to standards assures firms revenues over their patents.

High-intensive R&D firms are able to introduce patents of lower quality than outsiders and firms with small patent portfolios to a specific standard. The reason for this is that the stronger the protection of own technological know-how, the higher the likelihood to join formal SSOs to leverage the value of their technological portfolio (Dahlander and Wallin, 2006; Blind and Thumm, 2004). For this reason, high-intensive R&D firms are more powerful and have more influence in standards (Baron and Delcamp, 2010). On the other hand, companies that have strong intellectual property rights have such a strong position that they do not need the support of standards to market their products successfully (Blind and Thumm, 2004). The reason for this is that if firms participate in SSOs there is a possibility that they destroy their competitive advantage against their competitors, which has a negative effect on the firm's performance.

Furthermore, SSOs provide lower information asymmetries between firms hailing from different nations and allows more efficient organization of vertical relations in a bilateral trade relationship (Clougherty and Grajek, 2013). These firms are part of SSOs, because it allows them to capture value from their patents without having to enter cross–license negotiations with much larger customers and/or rivals. Furthermore, cooperation between a subgroup of member firms tend to increase the R&D efforts when a strong public good regime prevails in equilibrium, and can thus mitigate coordination failure at the SSO level (Baron et al., 2014).

SSOs create incentives for small firms to disclose more in order to ensure that they benefit from the licensing fees (Simcoe, 2007). In this way small companies, like start-ups, could benefit from their patents (Graham et al., 2009; Waguespack and Fleming, 2009).

However, some smaller firms do not have the possibility to cross-license their patents, because the costs and resources to negotiate the cross-license agreements are not justified by their income (Blind et al., 2011).

Companies have a lower tendency to join a SSO if they have a high intensity of patenting, because the transaction costs for integrating the patent-protected technologies are high (Delcamp and Leiponen, 2014). Other reasons are that there could exist a free-rider problem in SSOs, which causes a significant decrease in the incentives to invest in R&D, slow down innovation, and might ultimately reduce consumer and social welfare (Cabral and Salant, 2014). Besides that, the quality of the patents introduced by members of the SSO significantly decreases over time, so that innovations are not possible and firms mitigate intensive patenting (Baron et al., 2014).

Furthermore, SSOs require firms to disclose their patents. If there are no explicit rules for disclosure there could still be private information, which leads to higher royalty-fee licensing compared to SSOs where the disclosure requirements are high (Ganglmair and Tarantino, 2014; Chiao, Lerner and Tirole, 2007).

Firms that disclose their technical knowledge, which means that they reveal their patent documents, to open standard-setting organizations receive a higher company valuation than firms that do not disclose their patents to SSOs (Hussinger and Schwiebacher, 2015). The reason behind this is that standard-setting organizations exist in industries that have complex technologies and the demand of interoperability is high (Lemley, 2002). Components provided by different suppliers and products provided from different market segments can be combined to form a larger technical system (Hussinger and Schwiebacher, 2015). Standard-setting organizations could form this larger technical system, and customers or the market values this, because it leads to a higher availability of variety of complementary and compatible products. Besides that, standard-setting organizations have a higher user base than stand-alone firms and markets try to stick to organizations that are dominant in the market (Shapiro and Varian, 1999). Thus, firms that are participating in standard-setting organizations receive a higher valuation by the market (Hussinger and Schwiebacher, 2015). Simcoe (2007) find that open standard-setting organizations earlier achieve a widespread adoption than closed standard setting organizations.

The influence of participating in SSOs has an even higher effect on high-intensive R&D firms. The reason that high-intensive R&D firms receive a higher market valuation is due to the quality signals (Hussinger and Schwiebacher, 2015).

Technology contributions are not always patents, and patents reveal some quality of the technology contributions that firms provide to standard-setting organizations. R&D is the input of creating the output of patent applications. Firms that declare their patents as essential to standards are obliged to disclose their patents. Therefore, the market could form an assessment of the technical value of technology's disclosure of the patent and this gives a quality signal in order to value a company. Moreover, the market valuation of firms is a forward-looking measure for the returns on investments in different assets (Hussinger and Schwiebacher, 2015). High-intensive R&D firms will benefit from their R&D investments in the future. Thus, giving the market the opportunity to value the technological contributions to the standard settings organizations gives a better presentation of the firm's value.

2.5 Standard essential patents

Firms in standard setting organizations declare their patents to the standards. Standards are implemented and developed to create new technologies and products. Standard-essential patents (SEPs) are needed patents for adopting or implementing a technology standard (Pohlmann, Knut and Neuhausler, 2015). Intellectual property right holders could obtain a substantial leverage of the patent's value if its patents are included in the list of essential patents in standard setting organisations (Berger, Blind and Thumm, 2012). Moreover, patents increase in value if they are essential to standards (Rysman and Simcoe, 2008). Besides that, a company's position in a standard strongly depends on the number of SEPs (Bekkers et al., 2012). Firms with more standard-essential patents have more influence in standard-setting organizations. The benefits of declaring an essential patent to a standard is that the firm with the SEPs has leverage to control markets that are based upon the standardized technology. Essential patents create more bargaining power in negotiations with competitors and firms earn higher royalty payments, since firms could be forced to license their relevant patents in order to implement the standard (Berger, Blind and Thumm, 2012). So having more essential patents in a standard offers more freedom to firms and allows firms for leveraging their SEPs as a resource in licensing discussions (Blind et al., 2011). Besides that, firms that have essential patents in standards could create barriers to entry and could collude with other firms in the standard through horizontal co-operation, so that they could dominate an industry (Berger, Blind and Thumm, 2012).

The main negative effect of declaring patents is that a firm's competitive advantage could be reduced (Aggarwal, Dai and Walden, 2011). The reason for this is that firms are required to cross-licensing their patents in standards.

This leads to a higher homogeneity of knowledge distribution among the market participant and therefore reduces its competitive advantage (Pohlmann, Knut and Neuhausler, 2015).
Furthermore, firms could strategically declare their essential patents to standards and this could create a hold-up problem (Berger, Blind and Thumm, 2012; Caviggioli and Ughetto, 2013). Competitors of firms could declare patents to standards that are pending for a long time. Other firms that have not declared their patents to standards are facing a risk, because a valid blocking could occur. As a result, firms underinvest in R&D spending and technological development delays (Farrell et al., 2007; Berger et al., 2012). Another possibility is that a patent holder can charge royalties up to the switching costs before firms reconsider their decision on standards (Simcoe, 2007). Another negative effect that could arise is that the too many standard-essential patents in a standard could lead to several patents that contribute little to the standard or are not essential to the standard anymore (Bekkers et al., 2011). On the other hand, a patent that is worthless prior to standardization is valuable if affirmation by a standard-setting organisation leads to substantial technology–specific investments (Simcoe, 2007).

3. Hypothesis development

Essential patents are required to license under F/RAND terms, which positively influences the revenues of a firm (Layne-Farrar, Padilla and Schmalensee, 2007). Technology contributions to open standards have a positive influence on the valuation of the company as long as they explicitly refer to the associated patent documents (Hussinger and Schwiebacher, 2015). Firms that have patents on strong technologies will select an SSO aiming to receive the highest possible licensing revenues (Pohlmann, Knut and Neuhausler, 2015). Firms that have weak patents on their technologies make concessions to the users by signing a royalty free agreement for essential patents incorporated in a standard (Pohlmann, Knut and Neuhausler, 2015).

However, licensing too many patents to a standard could lead to a lower market value (Hussinger and Schwiebacher, 2015). The reason for this is that declaring too many patents to a standard might have a negative influence on the usage of the standard (e.g., expensive and less attractive), which decreases the demand for the standardized technology (Patterson, 2002). The demand of a standard consists of two components. First, there are technical advantages due to the invention. Inventions created by standards are accepted by the industry and consumers demand the standardized inventions.

This means that firms that are part of a standard benefits from this by receiving revenues compared to firms that are not part of a standard, because these products are not commonly accepted within the industry (Patterson, 2002). The second component of the demand of standards is the interoperability between firms in standards. Declaring too many patents could decrease the interoperability of a standard and this has a negative influence on the usage of the standard. It becomes less attractive and more expensive. If the second component of the demand of the standard is larger than the first component than the demand of standard decreases. This also has a negative effect on the standardized technology (Patterson, 2002). Pohlmann, Knut and Neuhasler (2015) find an inverse U-shaped relationship between owning standard-essential patents and their financial performance. Essential patent declarations increase the firm's value up to a certain optimal level and after that the positive effect decreases by declaring more essential patents than the optimal level. So, if too many patents are licensed the market value of firms could decrease more than the royalty fees that firms receive (Arora and Fosfuri, 2003). Besides that, declaring new SEPs increases the cumulative royalty fee of a standard, but also decreases a firm's share of the overall licensing income (Pohlmann, Knut and Neuhausler, 2015). Firms could only benefit from the royalty rates for standard-essential patents if the royalty rates are balanced (Hytonen et al., 2012). This leads to the following hypothesis:

H1: Standard essential patents have an inverse U-shaped relationship with the firm's performance.

Firms could have patented a technology with the purpose of including it in a standard, but a standard-setting organization did not accept the technology to be essential for the standard. Besides that, multiple competing patent technologies could be used to develop new standards, but none of these patents are considered as SEPs (Baron and Pohlmann, 2015). The patents that are not covered in the standard but are relevant for a standard are called standard-related patents. Firms that disclose standard-essential patents to standards in standard-setting organizations could have patents that are not included in the standards, but are related to the standards. In this thesis I assume that the standard-related patents have the same pattern as standard-essential patents on the firm performance of a company.

H2: Standard-related patents have an inverse U-shaped relationship with the firm's performance.

Patent citations also have an influence on the firm's performance. Research shows that there is a positive relationship between the patents citations per patent granted and the firm's performance (Hall, Jaffe and Trajtenberg, 2005; Narin, Noma and Perry, 1987). Although, the market value is positively correlated with the share of self-citations out of total citations to a firm's patents, this link gets weaker if the size of firm's patent portfolio increases (Hall, Jaffe and Trajtenberg, 2005). Hall and Macgreavie (2010) find that patenting high-cited inventions has a significant effect on the market value, but patents that do not increase the total stock of citations have a negative effect on the market value of a firm. So too many patents in a patent portfolio could lead to a negative effect of the total stock citations on the market value of a firm. According to Hall (2000), citation-weighted patents improve the precision between the valuation by the market and the patents of a firm. Citation-weighted patents are a better measure of economic value than simple patent counts for two reasons. First, research shows that patents weighted by their citations have a higher predictive power on Tobin's Q compared to simple patent counts (Shane, 1993). Second, citation-weighted patents are more highly correlated with R&D than simple patent counts, which means that firms invest more in patent innovations that ultimately lead to more citations (Hall, Jaffe and Trajtenberg, 2005). This thesis evaluates only the total stock citations of standard-related patents and does not evaluate citation-weighted standard-essential patents due to restrictions in the data. The reason for this is that the dataset does not provide the amount of citations per standard-essential patent.

H3: Citation-weighted standard-related patents have an inverse U-shaped effect on the market value.

This thesis investigates whether patents that are related to standards perform better than patents that are unrelated to standards. According to previous research, licensing patents has a positive effect on the firm's revenues through royalty fees or through market income (e.g., promoting their preferred technology) (Lichtenthaler, 2011). However, for investors it is hard to predict what the impact of patents is on future prospects of new technologies or products of a firm (Hirshleifer, Hsu and Li, 2013).

In standard-setting organizations inventors of different technological methods, users of the technology and other stakeholders come together to set methods so that technologies and products are invented for common use (Baron and Pohlmann, 2015). After that, SSOs develop standards to create products and new technologies. This means that patents that are related to standards could contain more information for investors about the future prospect of the new technologies and products. Hall, Thorma and Torrisi (2007) find that patents that contain more information receive a higher valuation than other patents. Furthermore, patents that are declared to a standard receive twice as many citations compared to patents that are not declared to standards (Rysman and Simcoe, 2008)[3]. According to Rysman and Simcoe (2008), this indicates that standard-related patents are more valuable or more important than patents that are unrelated to standard. These researches indicate that standard-related patents have a higher impact on the market value of firms compared to standard-unrelated patents.

H4: Firms with standard-related patents receive a higher market value compared to firms with unrelated standard patents.

4. Research method

This thesis investigates whether patents could provide value-relevant information to investors. In this thesis I distinguish patents in three different types. First, I determine whether patents of firms are essential to standards. Second, firms with standard-essential patents could have patents that are related to standards, but are not part of a standard. The last type of patents is a patent that is not essential or not related to standards. I obtain information for the first two types of patents from the Searle Center on Law, regulation and economic growth database and obtain information about patents that are not essential or not related to standards from the KPSS database. This thesis performs two different tests. First, I test whether standard-related and standard-essential patents have an influence on the firm's performance. Second, I test if standard-related patents have higher influence on the firm's performance compared to patent unrelated to standards. The research method is divided in three sections, the data section is structured in two subsections and the last section describes the methodology to test the hypotheses. Subsection 4.1 describes the sample size for firms with standard-related patents. This sample size is used to test the first three hypotheses.

[3] The citation rate of patents in SSOs is even higher if firms disclose their patents (Rysman and Simcoe, 2008).

In other words, this sample size tests the influence of patents related to standards, both standard-related and standard-essential patents, on the firm's performance. Furthermore, it tests whether citation-weighted standard-related patents show a similar relation with the firm's performance of a company as a simple patent count. Subsection 4.2 describes the sample size for firms with standard-unrelated patents and matches firms with standard-related patents to firms with standard-unrelated patents. This sample size tests the hypothesis that standard-related patents have a higher effect on the firm's performance compared to unrelated standard patents. The total number of observations for firms with standard-related patents on a firm-standard-year level is larger in the latter sample size. The reason for this is that firms with standard-related patents should be matched to firms with standard-unrelated patents.

The total number of observations for firms with standard-unrelated patents on a firm-year level significantly differs from the total number of observations for firms with standard-related patents. In order to get a sufficient sample size more observations on firm-standard-year level of firm with standard-related patents are included. Subsection 4.3 describes the methodology for the multiple regressions and propensity-score matching model.

4.1 Panel data standard setting organizations

This thesis includes a larger dataset of information about standard-setting organizations compared to previous research. Searle Center on Law, Regulation and Economic Growth provides a database that tracks standard development, innovation and corporate involvement by 233 firms in 515 important technology standards. The dataset contains data from 1992 till 2011 and includes 39,121 observations on a firm-standard-year level. The database provides information about standard-related patents, its citations and the total number of essential patent declarations of firms to standard-setting organizations. The database contains information about the number of firm members of a standard for each year. Furthermore, it describes the characteristics of the standard and specific financial data about each firm (i.e., total employees, sales and R&D expenses). I restrict the sample size to standards with more than four firms declaring their patents to standards (Baron, Pohlman and Ménière, 2014; Baron and Pohlmann, 2013). I exclude missing values of standard-related patent filings, patent citations and declarations of standard-essential patents from the dataset as well as the missing observations of the specific financial data (sales, R&D expense and employees). Furthermore, all the missing values of the characteristics of standards are recoded to zero.

These characteristics are the standard adoption by the industry, the cumulative forward references of standards, the cumulative number of releases of equivalent standards at other standard setting organizations, the patent classifications for the standard-related patents and the version age for each specific standard. Table 9 in the appendix provides an overview of total variables used from the Searle Center database.

I use the Wharton Research Data Services system to obtain the financial data about the companies in the standard database. The accounting data of U.S. companies is collected from the COMPUSTAT Fundamentals Annual database. I use the financial variables net income, total assets, total equity and the share price at the end of the year. The financial data is obtained to calculate the dependent variables Tobin's Q and return on assets (ROA). First, I drop all the missing values of the financial data that is collected. Second, I restrict the analysis by keeping the total assets that are positive. After calculating the Tobin's Q and ROA of each firm the outliers are deleted. The highest one per cent and lowest one per cent are excluded, so that the outliers do not influence the results. In order to keep a sufficient set of observations I winsorize other extreme outliers. Table 10 in the appendix provides an overview of the financial data variables that are used to calculate the Tobin's Q and ROA and to control for firm size.

In order to test whether patents related to standards have an influence on the firm's performance I have to match the COMPUSSTAT database with the Searle Center database. First, I match the header CUSIP code with PERMNO code for each firm. The CUSIP code is a unique identifier for each North American company and the PERMNO code is a permanent security identification number assigned by the Center for Research in Security Prices (CRSP). Matching the header CUSIP and PERMNO code for each firm ensures that I have unique firms in the COMPUSSTAT database. After identifying unique firms in the COMPUSSTAT database I manually match the firms in the Searle Center with their header CUSIP code. The reason for manually matching the company names with their CUSIP code is because the company names are described differently in the Searle Center database compared to databases that contain the CUSIP code for each firm. Based on the header CUSIP code I match the COMPUSSTAT database with the Searle Center database to retrieve the sample size for firms with patents that are related to standards. The sample size consists of 6749 observations and these observations are given on a firm-standard-year level between the periods from 2000 to 2008. The panel data contains 183 standards and in total 38 firms. This means that firms participate in multiple standards in a given year.

All the standards are part of seven main standard-setting organizations (ETSI, ITU-T, IEC, IEEE, JTC1, ITU_R, ISO). These standard-setting organizations are the most important standard-setting organizations and have a high influence on different industries. The standard-setting organizations are all formal SSOs. A description of the purposes and responsibilities of each SSO is provided in table 11 of the appendix. There are several differences between the standard-setting organizations in this sample size. First of all, the SSO JTC1 is a joint committee of two other standard-setting organizations: ISO and IEC. Furthermore, the number of standards significantly differs between the SSOs. Most of the standards are operating under the SSO ETSI and the SSOs IEC and ISO developed only one standard. Table 12 in the appendix gives an overview of the statistics of the SSOs.

4.2 Panel data for firms in SSOs and firms not in SSOs

So far I retrieved data of firms with standard-essential and standard-related patents. I obtain patent information about patents that are unrelated to standards through a different database than the patent data about patents related to standards. Noah Stoffman from Indiana University provides a KPSS patent database of firms from the periods between 1926 and 2010. This dataset contains both standard-related as standard-unrelated patents. This database has detailed information about firm's level innovation for each year. It contains the number of patents a firm has and the citation-weighted value of the patents as well as the number of citations per patent. In the KPSS database each patent is linked with a PERMNO code, which is the identification number for each firm. I link the patent database with financial data for each firm. The financial data for each firm in North America is collected from COMPUSTAT Fundamentals Annual database. I collect the net income, total assets, total common equity and the stock price at the end of year to calculate the Tobin's Q and ROA of a firm. To match the financial data for all patent firms with the KPSS patent database I first match the PERMNO code with the header CUSIP code and GVKEY code for each company that is retrieved from the CRSP database. After that, I match the patent database with the COMPUSTAT database based on the header CUSIP and specific year for each company. This gives a database of 25,414 observations on a firm-year-level with a time frame from 1992 till 2010.

The KPSS database contains patent data about standard-related and standard-unrelated patents. However, I cannot distinguish standard-related and standard-unrelated patent from each other, because no information is provided in the KPSS database about the type of patent (i.e., standard-essential, standard-related or unrelated).

I use the original database from the Searle Center on Law, Regulation and Economic Growth to retrieve the information for firms that have patents that are related to firms, so that I have firms with standard-related patents and firms with standard-unrelated patents. I exclude the firms from the KPSS database that are overlapping with the firms from the Searle Center database. After this, I have two different databases that contain different patent data. The Searle Center database contains patent data about firms with standard-related patents and the KPSS database contains patent data about firms with standard-unrelated patents. The two different databases give the possibility to test whether firms with standard-related patents have a different effect on the firm's performance than firm with standard-unrelated patents. In order to test this effect I have to match firms with standard-related patents to firms with standard-unrelated patents. The KPSS database contains 3,035 firms with standard-unrelated patents, whereas the Searle Center database contains 2059 firm-standard pairs with standard-related patents[4]. However, I first have to exclude several observations so that I could match the firms with the two different patent types and to obtain a sufficient sample size.

From the Searle Center database I exclude observations with missing values of standard-related patents. After that, I exclude the observations that have three or less declaring firms in a standard. I do not follow the approach of previous research for this sample size, otherwise there are too little firm-standard pair observations included in the sample size to match with firm that have standard-unrelated patents (Baron, Pohlman and Ménière, 2014; Baron and Pohlmann, 2013). After that, I manually match the database of the Searle center with the header CUSIP, GVKEY and PERMNO code of a company that are retrieved from the CRSP database. The reason for matching these codes manually with the patent data provided by the Searle Center database is because the presentation of the company name is different in Searle Center database compared to the CRSP and COMPUSSTAT database. After that, I retrieve the financial data from the North America companies through the COMPUSSTAT database. I collect the same financial data as the KPSS database to calculate the Tobin's Q and ROA for each firm. I match the Searle Center database with the COMPUSSTAT database by the header CUSIP of each firm. In total there are 9,224 observations on a firm-standard-year level that contain information about standard-related patents and these observations are spread over the years from 2000 till 2008.

[4] It is possible to match firms that have standard-unrelated patents with firm-standard pairs that have standard-related patents, because firm-standard pairs contain different patent data in each standard.

In order to match the firms in the KPSS database with the firm in the Searle Center database I use the same time periods. After that, I append the KPSS database with the Searle Center database. I include a dummy that indicates whether a firm is part of a SSO or not, so that I distinguish firms with standard-related patents from firms with standard-unrelated patents. I retrieve from the COMPUSSTAT database the standard industry classification (SIC) code for each firm. The reason for this is that I match the firms with standard-unrelated patents to firms with standard-related patents by their industry. The SIC codes of the companies identify in which industry a firm is operating. I only classify the main industry of each firm. The classification of the industry is provides in table 12 of the appendix. I exclude the observations of firms with standard-unrelated patents that operate in different industries than firms with standard-related patents.

However, this thesis tests whether standard-related patents have a larger effect on the firm's performance of a company than standard-unrelated patents. I deal with this by including lag variables of the patents and firm characteristics. I exclude the missing values of the lagged variables, so that the sample size is sufficient to test the different effect of standard-related and standard-unrelated patents on the firm's performance. The sample size contains 1702 firms with standard-unrelated patents and 47 firms with standard-related patents. However, these 47 firms could be part of multiple standards in a given year and I match the firm with standard unrelated patents to firm-standard pairs that have standard-related patents.

4.3 Methodology

This thesis tests two different effects that could reveal if patent provide value-relevant information. First, I test the relationship between standard-essential and standard-related patents and the firm's performance to indicate if disclosure of the patents that are part of standards and standard-setting organizations provide value-relevant information to investors. Second, I test whether standard-related patents have a different impact on the firm's performance than standard-unrelated patents, so that describing the type of patent could be value-relevant information for investors. I use two different research methods to perform the test. For the effect of patents related to standard on the firm's performance I use multiple regressions. I use a propensity-score matching model to match firms with standard-related patents to firms with standard-unrelated patents. After that, I use a linear regression to test whether standard-related patents have a higher impact on the market value of a firm than standard-unrelated patents. Therefore, the methodology section is divided in two parts.

Subsection 4.3.1 describes the methodology for the multiple regressions and subsections 4.3.2 describes the methodology for the propensity-score matching model.

4.3.1 Multiple regressions

Dependent variables

This thesis uses two measures to proxy the firm's performance. The first dependent variable is the return on assets (ROA). The return on assets measures the profitability of a firm relative to its total assets. Patents, which are classified as an asset on the balance sheet, could have a beneficial influence on the sales of a company. However, to obtain patents there are costs involved. First of all, obtaining new patents is mostly creating new knowledge. To create new knowledge research and development costs are involved. Once a company discovers new knowledge it should file its intellectual property to patents offices in order to obtain the patents. Filing patent applications to patents offices (e.g., European patent office (EPO) or United States Patent and Trademark offices (USPTO)) involve patent fees for the firm (USPTO, 2016). Furthermore, previous research shows that standard-essential patents, standard-related patents and citations have an influence on the ROA of firms (Pohlmann, Knut and Neuhausler, 2015). The ROA is calculated through the net income divided by total assets lagged by one year.

$$ROA = \frac{Net\ income_t}{Total\ assets_{t-1}}$$

The second dependent variable is Tobin's Q. Tobin's Q is a proxy to measure the market value of a firm. Tobin's Q is the ratio between the market value and replacement value of physical assets. The replacement value refers to value that a firm has to pay to replace an asset at a specific time. The replacement value could be seen as the book value of the assets a firm holds. Previous research shows that patents and patents citations have an influence on the Tobin's Q of a firm (Hussinger and Schwiebacher, 2015). I proxy Tobin's Q for each firm by the market value of equity at the end of the calendar year plus the book value of total assets minus book value of equity divided by book value of total assets.

$$Tobin's\ Q = \frac{\#shares\ outstanding_t * Closing\ price\ fiscal\ year_t + Total\ assets_t - Total\ Equity_t}{Total\ assets_t}$$

Independent variables

The main explanatory variable to test the first hypothesis is the standard-essential patent declarations to the standard-setting organizations. The total annual number of standard-essential patent declarations to all the standards per firm is a count for the total issued essential patents each year. Squared terms are added to the total declarations of essential patents for each firm to test for a non-linear relationship with the performance of each company (Pohlmann, Knut and Neuhausler, 2015).

The main explanatory variable for the second hypothesis is the standard-related patents to each standard. I use the number of standard-related patents on firm-standard-year level. This means that I use the total amount of standard-related patents for each firm to each standard per year. I also include squared terms included to test for a non-linearity relation between the standard-related patents and the firm's performance.

I follow the same methodology as previous research to test the third hypothesis (Pohlmann, Knut and Neuhausler, 2015; Hussinger and Schwiebacher, 2015). To test the relationship between patent citations and the firm's performance I calculate the average number of forward citations for each company. The average number of forward citations is calculated as the number of citations a firm's patent receive divided by the number of standard-related patents for each firm to each standard in a given priority year (Pohlmann, Knut and Neuhausler, 2015). Hall, Jaffe and Trajtenberg (2005) find that there is substantial time needed after the patent is granted to obtain information about its citations. So the benefits of citations for current or very recent innovations are not visible in the firm's performance in a current year. In order to deal with this, the number of forward citations received within four-year time window weights the citations a firm's patents. The time window assures that all the standard-related patents have the same time frame to be cited (Pohlmann, Knut and Neuhausler, 2015).

Other variables that are taken into account are the pool membership and the consortium membership of a firm. Companies that are a pool member are part of a patent pool. A patent pool is an association between at least two companies to cross-license all their patents to a particular standard. The number of patent pool memberships on the main standard (SSO) measures the variable pool members for each firm for a given year. Firms could be part of more patent pools in the same year, but this depends on the participation of companies in different standard-setting organizations. A consortium membership is almost the same as a pool membership.

The difference between the two memberships is that a member of consortium is partnering with other companies in the same standard instead of partnering in different standard setting organization. Thus, companies could be part of multiple consortia in the same standard-setting organizations, whereas companies could only be part of one patent pool in each standard-setting organization. A time-variant dummy that indicates the total number of membership for each firm in a given year measures the number of consortium membership.

Control variables

In the multiple regressions are several control variables included to control for firm characteristics and for standard characteristics to test whether the main explanatory variables, which are the standard-related patents, citations and the total declarations of standard essential patents, have an influence on the firm's performance. To control for the size effects of firms the total assets of a company are included. Patents could have an influence on the revenues and expenses of a company. To control for the efficiency of generating sales, the total sales per employee is included (Pohlmann, Knut and Neuhausler, 2015). Besides that, the R&D intensity of firms is included, which is measured by the R&D expenditures divided by the total sales for each given year. The R&D intensity is included, because it affects the firm's profitability for each company. This especially counts for high-intensive R&D firms.

I follow the approach of Baron, Ménière and Pohlmann (2014) by controlling the multiple regressions for other standard characteristics. To control for the timing of innovation with respect to standardization there are dummies of standard age included. The version age of the standards, which is measured by the number of years elapsed since the last version release, is also added to the regressions. I also control for influences caused by standards. First of all, the number of references that each standard receives from other standards is included. Second, the cumulative number of releases of equivalent standard at other SSOs is included as a control variable. Furthermore, a control variable for time-variant standard events that affects its commercial and technological importance is included. The number of mentions of the standard in news feeds measures the time-variant standard events on a year-level.

According to Baron, Ménière and Pohlmann (2014), including year dummies to control for confounding level effects that occur over the panel period cause a multicollinearity problem. To confirm this I regress the Tobin's Q of a firm on the independent variables and control variables mentioned before and find that there exists a multicollinearity problem. The reason for this is that I added standard fixed effects and standard age that cause the problem of multicollinearity by adding the year dummies.

In order to control for external shocks and time trends the international patent classification (IPC) for the overall number of standard-related patents for each year are included (Baron, Pohlmann and Ménière , 2014). There are two IPC classes that are included in the sample, which are the IPC-G and IPC-H class. The IPC-G class is for telecommunication standards and the IPC-H class is for IT standards.

Test for multicollinearity

There could exist some potential multicollinearity problems in the multiple regressions. For example, the standard-related patents could be correlated with total number of standard-essential patents declarations to all the standards. In order to deal with this I calculate the variance inflation factors (VIFs) to test for potential multicollinearity. The VIFs measure the multicollinearity between variables.

Multicollinearity indicates that two or more independent variables are highly correlated with each other. The problem that arises is that coefficient estimates are biased in case there exists multicollinearity. If there exists any multicollinearity between some independent variables the coefficients of the main explanatory variables could not give valid results.

Table 1 presents the VIFs scores for each independent variable. The mean of the VIFs is 1.29. The rule of thumb is that VIFs scores exceeding the value of ten require further investigation. However, the VIFs scores in our sample do not even exceed the value of two, so there are no multicollinearity concerns (O'Brien, 2007).

Multiple regressions

First of all, the return on assets of a firm are regressed on the independent variables. As independent variables the total number of standard-essential patents to the standards per company per year is included and to test for non-linearity the squared terms are added. Furthermore, the number of standard-related patents on a firm-standard-year level is included. Including squared terms gives the possibility to test for non-linearity. Furthermore, the average number of forward citations per company for each year and also the squared terms are included to test for non-linearity. The number of pool and consortium membership per company as well as the firm and standard characteristics are included in the model. As firm characteristics I include the R&D intensity, average sales per employee and the total assets (firm size). The standard control variables are the version age, the cumulative references received from other standards, the cumulative number of accreditations and the standard adoption by the market.

Table 1. Variance inflation factors (VIFs)
This table tests whether there exists multicollinearity between variables that are used in the multiple regressions. The variance inflation factors (VIFs) indicate whether there exists multicollinearity. The rule of thumb is that if VIFs scores exceed the value of ten then there could exist multicollinearity between the variables. However, this table shows that there are no multicollinearity concerns between the variables.

Variable	VIF	√VIF	Tolerance	R-squared
#Standard-related patents	1.08	1.04	0.923	0.078
#Citations/ #patents	1.01	1.00	0.991	0.009
#Essential patents	1.04	1.02	0.959	0.042
#Pool member	1.13	1.07	0.882	0.119
#Consortium member	1.27	1.13	0.790	0.211
Sales/employees	1.17	1.08	0.853	0.147
R&D intensity	1.43	1.20	0.698	0.302
Total assets	1.57	1.25	0.637	0.363
Standard adoption	1.00	1.00	0.998	0.002
Cumulative references	1.74	1.32	0.576	0.424
Cumulative accreditations	1.67	1.29	0.598	0.402
Version age	1.38	1.17	0.726	0.274
IPC control	1.17	1.08	0.858	0.142
Mean VIF	1.28			

To control for time effects and external shocks dummies of the standard age and a control variable for IPC are included. This gives the following model:

$$ROA_{i,t} = \alpha + \beta_1 * PAT_{i,t} + \beta_2 * PAT_{i,t}^2 + \beta_3 * \frac{CIT_{i,t}}{PAT_{i,t}} + \beta_4 * \frac{CIT_{i,t}}{PAT_{i,t}}^2 + \beta_5 * SEP_{i,t} + \beta_6 * SEP_{i,t}^2 + \beta_7 * POOL_{i,t} + \beta_8 * CONS_{i,t} + \beta_9 * Control_{i,t} + \varepsilon_{i,t} \quad (1)$$

with i=1,…..,n that stands for each company observation and t=1,…….,T that stands for each yearly observation. This means that ROA_{it} stands for the return on assets for company i in period t. PAT stands in the regression for the total standard-related patents for each firm in each standard and CIT/PAT stands for the average number of forward citations. SEP indicates the total number of standard essential patent declarations to all the standards. POOL and CONS are the total pool memberships and consortium memberships of a company in a given year. Control stands for the standard and firm characteristics and ε_{it} is the idiosyncratic error.

The other dependent variable that is used in this thesis is Tobin's Q. The variable Tobin's Q is positively skewed. To fit Tobin's Q better in the model a natural logarithm is taken. Log transformations make positively skewed distribution more normal. Furthermore, this thesis concerns about the efficiency of the market. It is possible that the impact of standard-related patents, the average number of forward citations and total essential patents is not directly reflected in market value of a firm. In order to deal with this Tobin's Q is measured in period t+1 and includes the Tobin's Q of the current period to show if markets are efficiently priced. This gives the following two models:

$$Ln(Tobin's\ Q_{i,t}) = \alpha + \beta_1 * PAT_{i,t} + \beta_2 * PAT_{i,t}^2 + \beta_3 * \frac{CIT_{i,t}}{PAT_{i,t}} + \beta_4 * \frac{CIT_{i,t}}{PAT_{i,t}}^2 + \beta_5 * SEP_{i,t} + \beta_6 * SEP_{i,t}^2 + \beta_7 * POOL_{i,t} + \beta_8 * CONS_{i,t} + \beta_9 * Control_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$Ln(Tobin's\ Q_{i,t+1}) = \alpha + \beta_1 * Tobin's\ Q_{i,t} + \beta_2 * PAT_{i,t} + \beta_3 * PAT_{i,t}^2 + \beta_4 * \frac{CIT_{i,t}}{PAT_{i,t}} + \beta_5 * \frac{CIT_{i,t}}{PAT_{i,t}}^2 + \beta_6 * SEP_{i,t} + \beta_7 * SEP_{i,t}^2 + \beta_8 * POOL_{i,t} + \beta_9 * CONS_{i,t} + \beta_{10} * Control_{i,t} + \varepsilon_{i,t} \quad (3)$$

This thesis does not perform an ordinary least square (OLS) regression for the multiple regressions, because this thesis deals with panel data where multiple firms operate in different standards and for multiple years. The problem that arises if the dependent variables are regressed on the independent variable through OLS regressions is that estimates of the coefficients may have an omitted variable bias. This happens when unknown variables cannot be controlled, but affect the dependent variable. Panel data could control for some types of omitted variables even if they are unobservable. In order to deal with this data structure I estimate the model by using a fixed effect regression model or random effect regression model. The random effect regression model assumes that company specific effects are uncorrelated with the independent variables. The fixed effect regression model is also called the within estimator and assumes time independent effects for each company that could be correlated with the independent variables. A Hausman test is performed to determine which regression model should be used for testing the hypotheses. The null hypothesis for the Hausman test states that both regression models are acceptable and the alternative hypothesis states that only the fixed effect regression model is acceptable. The Hausman test shows that the null hypothesis can be rejected.

This means that the random effects assumption is violated, which means that the company specific effects are correlated with the independent variables. The problem that arises is that coefficients and standard errors will be biased. Therefore, a fixed effect regression model is used to test the hypotheses. In order to see the effects of the main explanatory variables on the dependent variables I perform several models and will add extra variables to test the influence of the individual variables on the explained variable.

4.3.2 Propensity-score matching model

This thesis distinguishes patents from standard-related and standard-unrelated patents. Furthermore, this thesis investigates whether there is a different impact of the type of patents on the firm's performance. In order to test this I include a treatment effect that divides firms with standard-related patents from firms with standard-unrelated patents. I indicate that firms that are part of a standard-setting organization are firms with standard-related patents. I indicated these firms as the treatment group. To estimate the effect of a treatment on the firm's performance I should match the treated with the untreated, the control group. In the data I excluded the firms in the control group that operate in different industries than the firms in the treatment group. However, there still could be factors or confounding variables that make it difficult to match the firm in the treatment group with the firms in the control group, which could lead to biased results.

The statistical matching technique that I use that deals with this is a propensity-score matching test. The propensity-matching score test is the conditional probability of an assignment to a particular treatment given a vector of observed covariates (Rubin and Rosenbaum, 1983). I use a propensity-score matching test, because this test attempts to reduce the bias of confounding variables that could arise if simply comparing the treatment observations with the control observations (Rubin and Rosenbaum, 1983). For the propensity-score matching test I use a logistic model. The dependent variable in this model is the treatment outcome, which is that firms are either part of a SSO or not. As independent variables I use two firm performance measures and two firm characteristics. I use the same two firm performance measures as in the multiple regression section, which means that I use the Tobin's Q and ROA of a firm. I control for two firm characteristics. First of all, I control for the size of the company. As proxy for measuring the firm size of a company I use the total assets of a firm. I control for the R&D expenditures, because more expenditures could indicate more patents or higher valuable patents. I lag the variables with one year, so that I have more accurate matches between the control group and the treated group.

$$Logit\ SSO_{i,t} = \alpha + \beta_1 * Tobinsq_{i,t-1} + \beta_2 * ROA_{i,t-1} + \beta_3 * R\&D_{i,t-1} + \beta_4 * Size_{i,t-1} + \epsilon_{i,t} \quad (4)$$

SSO is a dummy variable that indicates 1 if firms are part of a SSO and 0 if firms are not part of a SSO. Tobin's Q and ROA are the performance measures for each company and are given for each year. The variable R&D stands for the expenditures in R&D in a given year, and size indicates the total assets of a firm in a given year.

The propensity-score matching test provides the matches between the treatment and control group to test whether firms with standard-related patents receive a higher market value compared to firms with unrelated standard patents. In order to test this hypothesis I use a linear regression. As a dependent variable to proxy the market value I take the Tobin's Q of a firm. The variable Tobin's Q is positively skewed.

To better fit Tobin's Q in the model a natural logarithm is taken. I include a dummy variable that indicates whether the patents are related to standards or unrelated to standards. Furthermore, I control for firm characteristics and include firm fixed effects and time fixed effects. The firm characteristics that I use are the total assets of a firm to control for the firm size of a company. Besides that, I control for the firm's profitability by including the R&D intensity of a firm. The R&D expenditures divided by the total revenue of a company measures the R&D intensity. This gives the following model to test whether standard-related patents lead to a higher market value than standard-unrelated patents:

$$Ln(Tobin's\ Q_{i,t}) = \alpha + \beta_1 * patents_{i,t} + \beta_2 * patents_{i,t} * SSODummy + \beta_3 * Total\ assets_{i,t} + \beta_4 * R\&D\ intensity_{i,t} + YearFE + FirmFE + \varepsilon_{i,t} \quad (5)$$

The dependent variable is the logarithm of Tobin's Q where i=1,…...,n indicates every company observation and t=1,.……,T indicates the yearly observation. The independent variable patents include both standard-related as standard-unrelated patents and the interaction effect with SSOdummy distinguishes the standard-related patents from the standard-unrelated patents. Furthermore, the total assets are the proxy for the firm size and the R&D intensity for the firm's profitability. YearFE and FirmFE are respectively the year fixed effects and the firm fixed effects and ε_{it} is the idiosyncratic error.

5. Results

The result section is divided in four sub-sections. The first sub-section provides descriptive statistics for the two different samples. I provide a descriptive statistic for the sample size that is used for the analyses of firm's performance with standard-related patents and standard-essential patents to standards. The second summary statistics contains the descriptive of the variables that are used for the analyses where SSO participants are compared to propensity-score matched control firms. The second sub-section provides the correlation matrix for the variables that are used to test whether standard-related and standard-essential patents have an influence on the performance of a company. The variables could be correlated with each other and therefore a correlation matrix is presented. Sub-section three provides the results of the relation between standard-related and standard-essential patents and the firm's performance. This sub-section tests the first three hypotheses of this thesis through multiple regressions. The results of the multiple regressions for each dependent variable are provided in table 5,6 and 7. For each dependent variable there are seven regressions. First of all, I regress the total number of standard-related patents, the average number of forward citations of standard-related patents and the standard-essential patents on the dependent variable and control for firm characteristics and standard characteristics. The last section presents the results whether firms with standard-related patents have a better firm's performance than standard-unrelated patents.

5.1 Descriptive statistics

Table 2 provides the summary statistics of the sample that is used to test the association between the patents that are related to standard-setting organizations and the firm's performance. Each variable contains the mean, standard deviation, minimum value and maximum value. The variables that are given are firm characteristics, standard characteristics and firm-standard characteristics. The firm characteristics are the number of employees, the total sales, R&D expenditures, the R&D intensity, employee turnover, Tobin's Q and ROA of a firm. These variables are measured on a firm-year level. This means that observations could contain the same firm values, but have different standard characteristics and firm-standard characteristics. The standard characteristics variables are the number of declaring firms of essential patents to standards, the standard age, standard adoption, cumulative references and cumulative accreditations. These variables are measured on a standard-year level. The number of declaring firms to a standard has a higher mean than the number of firms I use in the sample size.

The reason for this is that firms that declare their patents to standards could have missing values in the variables that I use. For example, a firm could have a missing value in the number of standard-related patents. I excluded all the missing values of the independent variables from the sample size. The standard age of a firm could be negative, because the standard age contains the value zero at the first release of a standard. Before the first release the standard age is a negative number.

The firm-standard characteristics variables are the number of standard-related patents, the number of citations for the standard-related patents, the total number of standard-essential patents declarations and the number of pool and consortium memberships. The variables are measured on a firm-standard-year level. The number of standard-related patents implies the total number of patents that a firm has in their patent portfolio that are related to a specific standard in a given year. The number of citations implies the total number of citations over a four-year time window of the total number of standard-related patents of a firm to a standard in a given year. The number of essential-patents is counted as the total declarations of SEPs to all standards in a given year. The pool and consortium membership is measured for each firm at each standard and standard-setting organization in a given year.

Table 3 presents the summary statistics of the variables used for the propensity-score matching model. The total number of patents is measured for firm with standard-related patents by the total number of standard-related patents on a firm-standard-year level. The total number of patents on firm-year level measures the total number of patents for firms with standard-unrelated patents. The two performance measures Tobin's and ROA as well as the firm characteristics R&D expenditures and total assets are measured on a firm-year level.

5.2 Correlation matrix

Table 4 presents a correlation matrix between the variables of the sample size used to test the relation between the patents that are related to standard-setting organizations and the firm's performance. The correlation matrix shows that there is a relation between the Tobin's Q of a firm and the standard-related patents, its citations and the total number of standard-essential patents a firm has. According to the correlation matrix, Tobin's Q has a positive relation with the standard-related patents and citations of the standard-related patents measured over a four year time-window and has a negative relationship with the total number of standard-essential patents. Furthermore, the correlation matrix shows that the ROA also is statistically significant related to the patents of a firm.

Table 2. Summary statistics variables multiple regressions

This table provides the descriptive of the main variables in the sample for the multiple regressions. For each variable the mean, standard deviation, minimum and maximum is given. Furthermore, the total observations for each variable are provided. The number of declaring firms is the total number of firms that declare their essential patents to a standard. The number of standard-related patents and citations are measured on firm-standard-year level. The number of essential patents is the total number of essential patents to all standards. The number of pool memberships is the total number of pool memberships in standard-setting organizations. The number of consortia memberships is the total number of consortia memberships in standards. The standard age, cumulative references and cumulative accreditations are measured on a standard-year level. The number of employees, total sales, R&D expense, Tobin's Q, ROA, employee turnover and R&D intensity are measured on a firm-year level.

Variable	Mean	Std. Dev.	Min.	Max.	#Obs
# Declaring firms	42.866	59.341	5	320	6749
# Standard-related patents (in thousands)	15.666	42.522	0	684.185	6749
# Citations (in millions)	0.262	0.997	0	2200	6749
# Essential patents	0.605	0.397	0.140	1.394	6749
# Pool member	0.027	0.162	0	1	6749
# Consortia member	0.118	0.322	0	1	6749
Standard age	3.686	4.782	-9	16	6749
# Cumulative references	5.672	14.522	0	113	6749
# Cumulative accreditations	0.863	2.113	0	13	6749
Standard adoption	0.207	2.491	0	130	6749
# Employees (in thousands)	125.414	133.861	0	484.000	6749
Sales (in thousands)	38.679	32.014	28.026	199.925	6749
R&D expense (in thousands)	2.799	2.116	1.718	8164	6749
Tobin's Q	2.711	2.068	0.709	14.404	6749
ROA	0.050	0.155	-1.175	0.332	6749
Employee turnover	0.409	0.185	0.012	2.083	6723
R&D intensity	0.136	0.139	0.001	0.847	6749

The R&D intensity of a firm is not statistically related to the declarations of standard-essential patents, but is related to the standard-related patents. The reason for this could be that the declaration of the essential patents occurs in a different time-period than the R&D expenditures of the invention of the patent. This means that patents are already part of the patent portfolio of a firm, but the standard is developed in a later stadium.

In this case, the standard-essential patents are unrelated to their R&D expenditures, because there is a different time-period. As expected there is a significantly strong relation between the standard-related patents and the citations of the standard-related patents. However, the relation between standard-related patents and the total number of standard essential patents to all standards is positively related, but there exists a weak association. The same correlation holds between the citations of the standard-related patents and the total SEPs to all standards in the sample.

Table 3. Descriptive statistics variables for propensity-score matching model
This table provides the descriptive statistics of the variables used to match the firms in standard-setting organizations with the firms in non-standard setting organizations. For each variable the mean, standard deviations, minimum, maximum and total observations are given. The Tobin's Q, ROA, total assets and R&D expense are measured on a firm-year level.

Variable	Mean	Std. Dev.	Min.	Max.	#Obs
Tobin's Q	2.242	1.283	0.903	6.276	13,615
ROA	0.018	0.160	-0.724	0.353	13,615
Total assets	31216.5	44040.45	7.613	797769	13,615
R&D expense	1801.901	2062.873	10	12183	13,615

5.3 Results of standard-related and standard-essential patents

5.3.1 ROA

In table 5 the ROA of a firm is regressed on the independent variables. The models in table 5 show that there is an U-shaped relation between the return on assets and the number of declared essential patents. This is in contrast with the first hypothesis, which states that there should be an inverse U-shaped relation between the number of SEPs and the performance of a company. Based on the models showed in table 5 standard-essential patents have a negative influence on ROA till a minimum point and after that there is positive effect on the return on assets if declaring more essential patents to the standard-setting organizations. Berger, Blind and Thumm (2012) provide two reasons for negative effects of declaring essential patents. First, standard-essential patents are restructured more often than other patents. This could include costs, which has a negative effect on the return on assets. Second, the approval of the application of an essential patent is significantly longer. The length of time to approval depends on the age of standard-setting organization. Applications of essential patents that are declared to standard-setting organizations in early stages of the standardization process have a higher degree of uncertainty about the specifications of the future standards, so the incentives to postpone the grant of the essential patents are high (Berger, Blind and Thumm, 2012).

Table 4. Pairwise correlations matrix of the sample variables
In this table correlations between variables are presented. A positive sign indicates a positive relation between the variables and a negative sign indicates a negative association. An association is stronger in case the number is closer to one and weak if close to zero. The stars in the matrix imply the significance level of the correlations between the variables. The interpretations of the significance level are as follows: *p<0.1, **p<0.05, ***p<0.01.

	# Declaring firms	# Pool members	# Consortium members	# Standard-related patents	# Citations	# Declarations essential patents	R&D intensity	Total assets	Tobin's Q	ROA
# Declaring firms	1.000									
# Pool memberships	0.105***	1.000								
# Consortium memberships	0.337***	0.073***	1.000							
# Standard-related patents	0.008	-0.050***	-0.116***	1.000						
# Citations	0.013	-0.039***	-0.078***	0.827***	1.000					
# Declarations essential patents	0.004	-0.0184	0.016	0.022*	0.030**	1.000				
R&D intensity	-0.019	-0.097***	-0.087***	-0.044***	-0.050***	0.020	1.000			
Total assets	0.005	0.118***	0.115***	-0.030**	-0.046***	-0.036***	-0.517***	1.000		
Tobin's Q	-0.061***	-0.087***	-0.039***	0.040***	0.050***	-0.170***	0.285***	-0.396***	1.000	
ROA	-0.057***	0.003	0.027**	0.046***	-0.035***	-0.027**	-0.281***	0.038***	0.289***	1.000

Table 5. Multiple regression of ROA

This table provides the results of the association between standard-related patents, average forward citations of standard-related patents and standard-essential patents on the return of assets of a firm after controlling for firm and standard characteristics. The stars in the matrix imply the significance level of the correlations between the variables and the interpretation is as follows: *p<0.1, **p<0.05, ***p<0.01. The values in the brackets indicate the standard errors of the coefficients. [1] indicates that the values of the coefficients are multiplied with 1000 to show the effect of the coefficient on the dependent variable. [2] indicate that the coefficients are multiplied with one million to observe the effect of the independent variable on the dependent variable ROA

Dependent variable: ROA	M1	M2	M3	M4	M5	M6	M7
# Standard-related patents	0.0004**			0.0004**	0.0004**		0.0004**
	(0.0002)			(0.0002)	(0.0002)		(0.0002)
# Standard-related patents sq.[1]	-0.0004			-0.0004	-0.0004**		-0.0004
	(0.0003)			(0.0003)	(0.0003)		(0.0003)
# Citations[1]		0.0002		0.002		-0.001	0.001
		(0.014)		(0.00001)		(0.0001)	(0.014)
# Citations sq.[2]		0.0002		0.0001		0.0002	0.0001
		(0.001)		(0.001)		(0.001)	(0.0001)
# Declared essential patents			-0.051**		-0.050**	-0.052**	-0.051**
			(0.022)		(0.022)	(0.022)	(0.022)
# Declared essential patents sq.			0.025*		0.025*	0.026*	0.025*
			(0.014)		(0.014)	(0.014)	(0.014)
# Pool memberships	-0.002	-0.001	-0.001	-0.002	-0.003	-0.002	-0.002
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
# Consortium memberships	0.030***	0.031***	0.032***	0.030***	0.031***	0.032***	0.032***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
R&D intensity	-0.548**	-0.558***	-0.553***	-0.543***	-0.537***	-0.547***	-0.531***
	(0.031)	(0.030)	(0.030)	(0.031)	(0.031)	(0.030)	(0.031)
Employee turnover	0.162***	0.159***	0.166***	0.162***	0.168***	0.165***	0.167***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Total assets[1]	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
	(0.00001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Standard adoption	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002	0.0001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Cumulative references	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.002***
	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0002)
Cumulative accreditations	-0.002	-0.001	-0.001	-0.002	-0.002	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Version age	-0.004***	-0.004***	-0.003***	-0.004***	-0.004***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
IPC control	0.004***	0.004***	0.006***	0.004***	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.489	0.560	0.410	0.552	0.403	0.472	0.464
	(0.396)	(0.400)	(0.396)	(0.400)	(0.396)	(0.401)	(0.401)
Standard dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2 within	0.2057	0.2046	0.2065	0.2059	0.2077	0.2067	0.2080

If the standard specifications of the SSO are known then the application process will be completed faster. Consequently, firms that declare little essential patents to standard-setting organizations could have a longer application process than firms that declare a lot of essential patents to SSOs. The positive relation between the declared essential patents and the ROA of a firm after the minimum point could be explained by the power of firms in SSOs. Having more essential patents in standards creates more freedom and allows firms for leveraging their SEPs as a resource in licensing discussions (Blind, et al., 2011). Firms receive licensing fees under the F/RAND terms of a SSO and this increases the revenue of a company and therefore the ROA.

Only one model, model 5, shows that the number of standard-related patents has an inverse U-shaped relation with the return on assets of a firm. The other models show that there is significant influence of the standard-related patents on ROA of a firm. However, the squared terms of the standard-related patents are not statistically related to ROA of a firm. Based on model five in table 5 there is an inverse U-shaped relation between the number of standard-related patents and the ROA of a firm. This means that the number of standard-related patents for each standard has a positive significant effect on the ROA of a firm to a certain point. So there is a maximum in standard-related patents to a standard in order to profit from the standard-related patents. The negative squared terms indicate that after a certain point standard-related patents have a negative effect on the ROA of a firm. Furthermore, citations do not have a statistical influence on the ROA of a firm. The reason for this is that citations do not contain a direct financial benefit for the company. This means that it does not have an impact on the net income of a firm and therefore it has no impact on the ROA of a firm.

According to table 5, the number of pool memberships of a company has no significant effect on the firm's performance. This could be explained by the different intellectual property policies of SSOs, which affect the licensing strategies of companies. Participating in pool is a specific licensing strategy for a firm. However, this thesis considers several SSOs, so the difference in licensing regimes could be explained through the SSOs instead of the pool memberships (Pohlmann, Knut and Neuhausler, 2015). Contrary, companies could be part of multiple consortia in one SSO. The models in table 5 show that participating in more consortia has a beneficial influence on the ROA of a firm. So pooling the resources with different companies in multiple standards leads to a better firm‘s performance.

A possible explanation for the positive relationship between being a member of a consortium and the ROA of a firm is due to network ties and the involvement of the firms to the consortium (Olk and Young, 1997). A higher involvement in a consortium could be explained by several reasons. First, firms contribute more resources and have better knowledge of and influence on the use of the resources. Second, there is a higher frequency of communication between the members of the consortium and the level of influence is higher for each member within the consortium (Olk and Young, 1997). Firms within a consortium could benefit from each other by using their resources for a lower price. The network ties that exist in a consortium create this effect and could have a positive impact on the ROA of a firm (Olk and Young, 1997).

The firm control variables increase the explanatory power of the models. Besides that, the R&D intensity and the sales per employee have a significant influence on the firm's performance. The models in table 5 show that there is a significant negative relation between the R&D intensity and ROA of a firm. A possible explanation for this is that the R&D intensity is measured by the R&D expenditures relative to their sales. However, these costs do not immediately have an impact on the sales of a firm. R&D expenditures are investments in new innovative processes or technologies and it is unsure whether the investments have a positive effect on the firm's performance or not. So the impact of the R&D expenditures on the sales of a firm will be observable several years after its investments. This means that the net income of a firm is only negatively influenced by its R&D intensity, because the R&D expenditures have a direct influence on net income of a company. This explains that R&D intensity of a firm consequently has a negative relation with its ROA. The delay between expensing R&D outlays and getting the benefits of the outlays is one reason for the mispricing of R&D intensive firms. The variable average sales per employee show that a higher labour productivity has positive effect on the firm's performance. The reason behind this is that the cost per employee (i.e., salary) stays the same, whereas the revenue per employee increases. The size of a company, which is measured by total assets, has no effect on the performance of a company.

Some standard control variables have a significant influence on the ROA of a firm. The standard adoption, which is the total number of mentions of the standard in new feeds per year, and the cumulative accreditations, which the cumulative number of releases of equivalent standards at other SSOs, do not have a significant influence on the ROA of a firm.

The cumulative references, which are the cumulative forward references received by other standards, have a positive effect on the ROA of a firm. If standards receive more forward references by other standards it indicates the importance and power of a SSO. The stronger a SSO, the more confidence and acceptance users have in the new products and technologies developed by the firms in the SSO (Blind, Gauch and Hawkins, 2010). This could have a beneficial effect on the sales of a company and therefore on the ROA. The version age of a standard, which is the total number of years, elapsed after the last version release of a standard, has a negative effect on the ROA of a firm. The version age of the standard implies the innovativeness of a standard. The longer the number of years elapsed after the last version release, the less innovative and active a standard is. This has a negative impact on the ROA of a firm. The IPC class relevance to a specific standard has a positive significant effect on the ROA of a firm. This means that telecommunication standards (IPC-G class) and IT standards (IPC-H class) have a higher ROA compared to standards that have a different IPC class. So declaring essential-patents to those standards has a beneficial effect on the performance of a company.

Based on the models in table 5, the patents related to standards and standard-setting organizations could contain valuable information about the ROA of firm. So incorporating the information of the patents in valuating the ROA of a firm could lead to lower mispricing of high-intensive R&D firms.

5.3.2 Tobin's Q

In table 6 and 7 are the models presented where Tobin's Q is regressed on the independent variables. Table 6 presents the effects of the independent variables on Tobin's Q in the same period and table 7 reflects the effects of independent variables on Tobin's Q one period later. However, the interpretation of the coefficients in tables 6 and 7 is different from table 5, because a natural logarithm is taken of the dependent variable.

Regressing Tobin's Q of a firm in the current period on the total number of SEP declarations to all standards gives only a significant effect for the non-squared terms of total number of SEPs. Based on the models it is hard to interpret the coefficients and the significant effect of the total number of declared essential patents to all standards on the Tobin's Q of a firm in the current period. However, the regression models in table 7 indicate that there is association between the total number of essential patents declarations to SSO's and the Tobin's Q of a firm. Based on the models in table 7, standard-essential patents have an inverse U-shaped relation with the market value of the firm in the next period.

The models control for the Tobin's Q of a firm in the current period. This means that the information about standard-essential patents is not consistent with market efficiency. The information is not valued directly in the market, but in the next period. To determine the effect of declaring essential patents to standards on the market value of a firm, the market value of the next period should be evaluated. This means that firms with standard-essential patents are mispriced in the market in the current period. Therefore, the market incorrectly values high R&D intensive firms with a lot of essential patents to standard in the current period. I partly confirm hypothesis 1, which states that standard-essential patents of a firm have an inverse U-shaped relation with firm's performance. I reject hypothesis 1 where the ROA of a firm is used as an indicator of firm's performance and accept hypothesis 1 where Tobin's Q is used to proxy the firm's performance. However, the information of the standard-essential patents only has an effect on the Tobin's Q in the next period.

The inverse U-shaped relation between the total number of SEP declarations to all standards and the Tobin's Q of a firm can be explained by several reasons. First of all, firms profit from standard-essential patents, because they are more worth than patents that are not essential to standards (Rysman and Simcoe, 2008). The reason for this is that firms with SEPs have a stronger position and more influence in a specific standard compared to firms that do not possess essential patents in a standard. Besides that, essential patents receive licensing revenues of the standards, so more essential patents leads to higher revenues. The possible explanation for the turning point could be that too many firms file their patents as essential to standards. Therefore, the usage of the standard becomes expensive and less attractive and the demand for the standardized technologies in a standard decreases (Patterson, 2002). This leads to a negative effect on the market value of a company.

According to all the models in tables 6 and 7, standard-related patents have an inverse U-shaped relation with the Tobin's Q in the current period. Increasing the number of standard-related patents with one unit has a positive influence on Tobin's Q in the same period of 0.20 per cent[5]. The logic behind this is that users have more confidence and a higher acceptance in the new products and technologies that are developed by firms in standard-setting organizations (Blind, Gauch and Hawkins, 2010). So patents that are related to standards increase the likelihood of developing new products and technologies.

[5] This percentage is based on the final model in table 6.

Table 6. Multiple regression on Tobin's Q in period t

This table provides the results of the relation between standard-related patents, average forward citations of standard-related patents and standard-essential patents on the Tobin's Q of a firm after controlling for firm and standard characteristics. The stars in the matrix imply the significance level of the correlations between the variables and the interpretation is as follows: *p<0.1, **p<0.05, ***p<0.01. The values in the brackets indicate the standard errors of the coefficients. [1] indicates that the values of the coefficients are multiplied with 1000 to show the effect of the coefficient on the dependent variable. [2] indicate that the coefficients are multiplied with one million to observe the effect of the independent variable on the dependent variable Tobin's Q.

Dependent variable: ln(Tobin's Q)	M1	M2	M3	M4	M5	M6	M7
# Standard-related patents	0.001***			0.002***	0.002***		0.002***
	(0.0004)			(0.0004)	(0.0004)		(0.0004)
# Standard-related patents sq.[1]	-0.002***			-0.002***	-0.002***		-0.002***
	(0.001)			(0.001)	(0.001)		(0.001)
# Citations[1]		0.257***		0.263**		0.255***	0.262***
		(0.034)		(0.034)		(0.033)	(0.033)
# Citations sq.[2]		-0.015***		-0.015***		-0.014***	-0.015***
		(0.002)		(0.002)		(0.002)	(0.002)
# Declared essential patents			-0.103**		-0.103**	-0.118**	-0.117**
			(0.053)		(0.053)	(0.052)	(0.052)
# Declared essential patents sq.			-0.042		-0.043	-0.034	-0.035
			(0.034)		(0.034)	(0.034)	(0.034)
# Pool memberships	0.082**	0.080**	0.081**	0.076*	0.077**	0.075*	0.070*
	(0.040)	(0.039)	(0.039)	(0.039)	(0.039)	(0.038)	(0.038)
# Consortium memberships	-0.011	-0.003	0.016	-0.004	0.014	0.023	0.021
	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
R&D intensity	-0.749***	-0.837***	-0.660***	-0.782***	-0.601***	-0.696***	-0.633***
	(0.076)	(0.074)	(0.073)	(0.075)	(0.074)	(0.072)	(0.073)
Employee turnover	0.235***	0.192***	0.249***	0.202***	0.260***	0.218***	0.229***
	(0.046)	(0.046)	(0.045)	(0.046)	(0.045)	(0.045)	(0.045)
Total assets[1]	0.001***	0.001***	0.004*	0.001**	0.0003	0.0003*	0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Standard adoption	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Cumulative references	0.0005	0.0005	0.052	0.0005	0.0001	0.0001	0.0001
	(0.001)	(0.001)	(0.672)	(0.001)	(0.001)	(0.001)	(0.001)
Cumulative accreditations	0.003	0.007	0.006	0.006	0.005	0.009	0.007
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Version age	-0.004	-0.004	-0.0001	-0.005*	-0.001	0.0002	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
IPC control	0.019***	0.020***	0.024***	0.020***	0.024***	0.026***	0.025***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Constant	1.958**	1.775*	1.548	1.748*	1.519	1.313	1.282
	(0.979)	(0.981)	(0.953)	(0.980)	(0.952)	(0.953)	(0.951)
Standard dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2 within	0.2439	0.2529	0.2871	0.2553	0.2898	0.2995	0.3025

Table 7. Multiple regressions on Tobin's Q in period t+1

This table provides the results of the relation between standard-related patents, average forward citations of standard-related patents and standard-essential patents on the Tobin's Q in the next period of a firm after controlling for firm, standard characteristics and Tobin's Q in the current period. The stars in the matrix imply the significance level of the correlations between the variables and the interpretation is as follows: *p<0.1, **p<0.05, ***p<0.01. The values in the brackets indicate the standard errors of the coefficients. [1] indicates that the values of the coefficients are multiplied with 1000 to show the effect of the coefficient on the dependent variable. [2] indicate that the coefficients are multiplied with one million to observe the effect of the independent variable on the dependent variable Tobin's Q in the next period.

Dependent variable: ln(Tobin's Q_{t+1})	M1	M2	M3	M4	M5	M6	M7
Tobin's Q	0.068***	0.069***	0.077***	0.069***	0.077***	0.079***	0.079***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
# Standard-related patents	0.001***			0.001***	0.001***		0.001***
	(0.0003)			(0.0003)	(0.0003)		(0.0003)
# Standard-related patents sq.[1]	-0.001**			-0.001**	-0.001*		-0.001
	(0.001)			(0.001)	(0.001)		(0.001)
# Citations[1]		-0.144***		-0.140***		-0.166***	-0.162***
		(0.027)		(0.027)		(0.026)	(0.028)
# Citations sq.[2]		0.007***		0.007***		0.008***	0.008***
		(0.002)		(0.002)		(0.002)	(0.002)
# Declared essential patents			0.293***		0.294***	0.279***	0.280***
			(0.041)		(0.041)	(0.040)	(0.040)
# Declared essential patents sq.			-0.098***		-0.099***	-0.088**	-0.089***
			(0.026)		(0.026)	(0.026)	(0.026)
# Pool memberships	0.065**	0.070**	0.070**	0.067**	0.067***	0.072**	0.069**
	(0.031)	(0.030)	(0.030)	(0.030)	(0.030)	(0.029)	(0.029)
# Consortium memberships	0.012	0.010	-0.006	0.009	-0.007	-0.009	-0.010
	(0.019)	(0.019)	(0.018)	(0.019)	(0.018)	(0.018)	(0.018)
R&D intensity	0.189***	0.171***	0.072	0.208***	0.110*	0.102*	0.135**
	(0.060)	(0.059)	(0.057)	(0.060)	(0.058)	(0.057)	(0.058)
Employee turnover	0.384***	0.382***	0.337***	0.388***	0.343***	0.346***	0.351***
	(0.036)	(0.036)	(0.035)	(0.036)	(0.035)	(0.034)	(0.034)
Total assets[1]	0.0001	0.0002	0.0003*	0.0002	0.0003*	0.0004**	0.0004**
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Standard adoption	-0.00001	0.0001	-0.0001	0.00003	-0.0001	-0.0001	-0.0001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Cumulative references	0.001***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Cumulative accreditations	-0.002	0.001	-0.004	-0.0003	-0.005	-0.003	-0.004
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Version age	0.005**	0.005**	0.002	0.004*	0.001	0.001	0.0002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
IPC control	0.012***	0.012***	0.003*	0.012***	0.003	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	-1.181	-1.190	-0.591	-1.209	-0.610	-0.625	-0.642
	(0.767)	(0.766)	(0.741)	(0.766)	(0.741)	(0.739)	(0.739)
Standard dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2 within	0.3915	0.3999	0.4345	0.4015	0.4361	0.4452	0.4465

Furthermore, for investors it hard to predict the future prospects of new technologies or other innovations, because it depends on the strategic plan of a firm and the major shifts in the industrial structure firms face (Hirshleifer, Hsu and Li, 2013). However, standard-setting organizations aim to achieve consensus on the specifications of a technology (Lyytinen and King, 2006). So having more standard-related patents gives investors a better indication of the future prospects of new technologies or products of a company. However, this only holds up to a specific maximum point. After that, an increase in the number of standard-related patents of firms has a negative influence on the Tobin's q of a firm.

According to table 7, one extra unit has a positive influence on the Tobin's Q of a firm of 0.10 per cent in the next period up to a specific maximum point. After that, there is a negative impact of having more standard-related patents to a specific standard in the patent portfolio of a firm. Based on these results and the results of table 5 I confirm hypothesis 2, which states that standard-related patents have an inverse U-shaped relationship with the firm's performance.

Based on table 7, the results indicate that standard-essential patents have a higher impact on the market value than the standard-related patents of firms. This implies that it is valuable for firms to have essential patents in standards. Furthermore, the results indicate that firms should balance their patent portfolio and should have both have standard-related as standard-essential patents in their patent portfolio.

Citation-weighted patents have an inverse U-shaped relation with the Tobin's Q in the current period of a firm. This means that the market values of a firm are higher if a firm receives more forward citations on average. Thus, more citations per patent increase the firm's performance. However, after a certain point there is a negative effect on the firm's performance. The models show that the pattern of the standard-related patents and the citation-weighted standard-related patents coefficients is identical over time. Furthermore, this result confirms hypothesis 3, which states that citation-weighted standard-related patents have an inverse U-shaped effect on the market value. However, comparing the effect of citation-weighted standard-related patents with the Tobin's Q in the current period and the Tobin's Q in the next period gives an opposite result. After controlling for Tobin's Q citation-weighted patents have an U-shaped relation with the Tobin's Q in the next period. This means that one extra citation per patent has a negative impact on the Tobin's Q of a firm in the next period up to a minimum point. After that, one extra citation per patent has a positive effect on the Tobin's Q of a firm. Based on the models in table 7 hypothesis 3 is rejected.

Compared to ROA, pool memberships have an influence on the Tobin's Q of a firm. The market value of a firm increases if firms choose the licensing strategy to pool their patents with other companies. Participating in one extra pool leads to an increase of 7.3 per cent of the Tobin's Q of a company in this period and to an increase of 7.1 per cent in the next period. This means that the participation of firms in patent pools in SSOs is smoothly included in the market value of a firm[6]. Participating in a consortium has no significant effect on the market value of firm.

The R&D intensity has a direct negative effect on the Tobin's Q and a positive effect on the Tobin's Q in the next period. As mentioned before this negative effect arises through the R&D expenditures of a firm. This expenditures have a direct impact on the net income of a firm and this has a direct impact on the Tobin's Q of a firm. The return on investments of R&D expenditures will be observable after several years, so after the current year R&D expenditures have a positive influence on the Tobin's Q of a firm. The reason for this is that investors have more forward-looking information on the development potential of products/technologies (Chen, Gavious and Lev, 2015). Thus, high-intensive R&D firms are mispriced in the current period and the market corrects this is in the next period. The sales per employee have the same effect on the market value as for the ROA of a firm. If all the employees on average increase their sales with one unit the Tobin's Q would increase with 26 per cent in the same period[7]. The average sales per employee also have a positive and significant effect on the market value in the next period. The control variable firm size has no effect on the Tobin's Q of a firm in the current period. However, the firm size of a company has a positive effect on the Tobin's Q of a firm in the next period. Although, the effect of the firm size on the Tobin's Q is almost negligible.

Some of the standard control variables have an effect on the Tobin's Q of a firm. The standard adoption and the cumulative number of releases of equivalent standards at other SSOs do not have a significant influence on the Tobin's Q of a firm. The number of years elapsed after the last standard release also does not have an influence on the market value of a firm. The cumulative forward references received by other standards have a positive effect on the Tobin's Q in the next time period. An extra thousand references received by the standard increase the Tobin's Q of a firm in the next period with 0.2 per cent[8].

[6] These percentages are based on the final models of table 6 and 7.
[7] This percentage is based on the final model in table 6.
[8] This percentage is derived from the coefficient in the final model of table 7.

The IPC class of a standard also has a positive influence on the Tobin's Q of a firm. If the standard is a IPC-G or IPC-H class than the Tobin's Q of a firm in the current period is on average 2.5 per cent higher compared to standard with a different IPC class[9].

5.4 Firm performance of standard-related patents and unrelated patents

The previous results show that there is a relation between the number of standard-related patents and the firm's performance of a firm in a SSO. However, these results do not show if standard-related patents perform different than standard-unrelated patents.

In other words, standard-related patents could have a larger impact on the firm's performance compared to standard-unrelated patents. I test this hypothesis by performing a propensity-score matching test to match the treated firms, which have standard-related patents, with the control firms, which have standard-unrelated patents. After that, I perform a linear regression with the matched firms to test whether firms with standard-related patents have a higher market value than firms with standard-unrelated patents.

To perform the propensity-score matching test I include the nearest neighbor matching within a specified caliper, which means that the propensity scores of matched subjects must be below a threshold (the caliper distance) (Austin, 2011). This leads to a better matching process. The propensity-score matching test gives in total 12,683 observations that have common support. This is the range of propensity scores that overlap across the treatment and comparison groups. However, the total number of matches between the treated and control group is low, because firm characteristics and firm performance characteristics are too different from each other. The reason for this is that I use two different datasets where the databases do not take into account firms with different types of patents, which means standard-related, standard-essential or standard-unrelated patents. In total I have 13 matched pairs of firms out of the 13,473 observations.

In table 8 the linear regression of the matched firms is provided. Based on table 8 patents do not have a statistical influence on the Tobin's Q of a firm. The reason for this is that the total number of observations is too low to show significant results. For this reason I do not find any support for the hypothesis that standard-related patents receive a higher market value by the market than standard-unrelated patents. However, the R&D intensity of a firm does have a statistical significant impact on the firm's performance. According to table 8, increasing the R&D intensity with one point, has a negative impact on the Tobin's Q of a firm of 14.3 per cent.

[9] This percentage is derived from the coefficient in the final model of table 6.

This means that R&D expenditures have a negative impact on the market value if the revenue remains constant over time. This result is similar to the results provided in table 6. Thus, based on this and the results of table 6 high-intensive R&D firms receive a lower market value than low-intensive R&D firms in the current year. The reason for this is that R&D expenditures have a negative impact on the net income of a firm in the current year, but the return on investment of the R&D expenditures is observable after the current year for several years.

Table 8. The linear regression of the propensity-score matching model
This table provides the linear regressions of firms that are matched through the propensity-score model. This linear regression regresses the Tobin's Q of a firm on the patents of a firm after controlling for firm characteristics. The total number of firms consists of a treatment group and a control group. The treatment group are part of a standard-setting organization and the control group are not part of a standard-setting organization. The stars in the matrix imply the significance level of the correlations between the variables and the interpretation is as follows: *p<0.1, **p<0.05, ***p<0.01. The values in the brackets indicate the standard errors of the coefficients.

	DV: logarithm of Tobin's Q
Patents	0.0853
	(0.162)
Patents*SSO	-0.087
	(0.165)
R&D intensity	-0.154**
	(0.065)
Total sales	0.0001
	(0.0002)
Constant	-1.782
	(0.034)
Firm fixed effects	Yes
Year fixed effects	Yes
R^2	0.9047
# Observations	26

6. Discussion and conclusion

This paper examines the value relevance of patents and the added value of standard-setting organizations on the information of patents. Firms that operate in standard-setting organizations declare their patents to standards and these patents could be essential for a standard. Standard-essential patents (SEP's) are the patents that are necessary when adopting or implementing a technology standard (Pohlmann, Knut and Neuhausler, 2015). The patents that are not covered in the standard but are relevant for a standard are called standard-related patents. Information of patents could be valuable for other firms. In order to use existing patents to develop patents, existing patents have to be cited. Citations are the references to previous existing patents and provide information about the innovations of firms (Hall, Jaffe and Trajtenberg, 2005).

I test whether standard-related patents and essential patent declarations to standards have an influence on the firm's performance. Besides that, I test if citation-weighted standard-related patents have a similar effect on the firm's performance as a simple patent count of the standard-related patents. Furthermore, I test whether standard-related patents receive a higher market value than standard-unrelated patents.

I use multiple regressions to test whether standard-related patents, standard-essential patents and citations-weighted standard-related patents have an impact on the firm's performance. The proxies for the firm's performance are the Tobin's Q and the ROA of a company in a given year. I find mixed results concerning the impact of essential patents on the firm's performance. Essential patents show a U-shaped relationship with the ROA of a firm and have an inverse U-shaped relationship with the Tobin's Q of a firm in period t+1. The reasons for a U-shaped relationship between the essential-patents and ROA of a firm could be explained by two reasons. First, firms that declare little essential patents to standard-setting organizations could have a longer application process than firms that declare a lot of essential patents to SSOs. The longer application process, the more costs are involved and therefore has a negative impact on the ROA. Second, having more essential patents in a standard setting organizations creates more freedom and allows firms for leveraging their SEPs as a resource in licensing discussions (Blind, et al., 2011). The inverse U-shaped relation between essential patents and the Tobin's Q of firm could be explained by two reasons. Firms receive licensing fees under the F/RAND terms of a SSO and this increases the revenue of a company and therefore the ROA. A turning point could arise if too many firms file their patents as essential to the SSOs. This leads to a too expensive usage of the SSO. Therefore, the SSO becomes less attractive and the demand for the standardized technologies in a SSO decreases (Patterson, 2002).

Furthermore, I find that there is an inverse U-shaped relation between the number of standard-related patents and the ROA and Tobin's Q of a firm. This means that firms benefit from having more standard-related patents in their patent portfolio to a specific maximum point and after that standard-related patents to a standard have a negative impact on the firm's performance. Citation-weighted patents show a similar relation with the Tobin's Q of a firm in the current period as the simple patent count of standard-related patents. However, I find that citations-weighted patents have a U-shaped relation with the Tobin's Q of a firm in the next period.

This means that after a minimum point an increase in the number of citations per patent has a positive impact on the market value of a company. The logic behind this is that patents that contain more citations by following up patents contain valuable information for new innovations (Hall, Jaffe and Trajtenberg, 2005).

I perform a propensity-score matching test to match firms with standard-related to firms with standard-unrelated patents in order to test if standard-related patents receive a higher market value than standard-unrelated patents. The propensity-score matching models do not provide enough matches to test sufficiently whether standard-related patents receive a higher market value than standard-unrelated patents. However, the regression model shows that the R&D intensity of a firm has a negative impact on the market value of the firm in a current year. The multiple regressions of the Tobin's Q in the current period on the standard-related, standard-essential and citation-weighted patents show similar results. This means that high-intensive R&D firms receive a lower market value by the market. The multiple regressions of the Tobin's Q in the next period on the standard-related, standard-essential and citation-weighted patents of a firm show opposite results. These results show that high-intensive R&D firms receive a higher market valuation in the next period. This means that high-intensive R&D firms are mispriced in the current period and other information about the R&D outlays could contain valuable information for investors to value a firm.

Overall, this thesis shows that the patents of a firm contain valuable information for investors. Although, this thesis does not show that standard-related patents have receive a higher market value than standard-unrelated patents it shows that standard-related and standard-essential patents have an influence on the firm's performance. The main reason for this is that standards of standard setting organizations gives investors a better indication of the future prospects of new technologies or products of a company (Hirshleifer, Hsu and Li, 2013). Furthermore, this thesis shows that essential patents have a higher impact on the Tobin's Q of firm compared to standard-related patents. This implicates that firms that with a relative high percentage of essential patents in their patent portfolio have a higher Tobin's Q than firms with a relative low percentage of essential patents in their patent portfolio. Furthermore, citation-weighted patents could also explain the inverse U-shaped relation with the Tobin's Q in the current period.

This thesis contributes to the academic accounting and innovation literature. This thesis shows that voluntary disclosure of patents could provide value-relevant information for investors.

This especially counts for firms that report under the US GAAP system, because the reporting of their R&D expenditures do not reveal any information about the future prospects of the development of new technologies and products. This thesis shows that firms should disclose more information about the characteristics of a patent, because it contains valuable information about the future prospects of new products and technologies. This means that firms should indicate whether a patent is essential for a standard, standard-related or is not related to any standards. Besides that, this thesis suggests that information about participating in standard-setting organizations also reflects information about the firm's performance. Voluntary disclosure of participation in standard-setting organizations gives investors better insights about the strategic plan of a company. Furthermore, patents could be used as indicator for the level of innovation. This thesis shows that patents that are essential to standards indicate that these patents are needed to develop new products and technologies and are therefore a relevant innovation measure. However, firms should balance their patent portfolio in order to give investors better insights about the value-relevance of their patents. This means that firms could also declare too many patents to standards, causing that several patents contributes little to the standard or are not essential to the standard anymore.

Furthermore, this thesis continues to identify the impact of standard-setting organizations on the firm's performance. This thesis shows different results compared to previous studies (Pohlmann, Knut and Neuhausler, 2015). This thesis shows that there is a U-shaped relation between the number of declarations of essential patents to standards and the return on assets of a company. This thesis contradicts the reason that licensing too many essential patents may decrease the market profits beyond licensing profits that results in a negative effect on the revenues and therefore the ROA of a firm (Arora and Fosfuri, 2003). However, there exists an inverse U-shaped relation between the SEP and the market value of a company. Furthermore, this thesis supports the empirical evidence that firms should balance their patent portfolio (Arora, Fosfuri and Ronde, 2013).

The main findings indicate that there should be a balance in the patent portfolio of firms. This study may improve the decision-making process of standardization managers. Based on previous research, this thesis suggests that firms that are participating in SSOs should collaborate more with different divisions in an organization (Rauber and Blind, 2013). Firms most of the time lack a common strategy between patent and standardization department. A common approach could lead to better decisions and a more balanced patent portfolio.

Furthermore, firms should better indicate in their financial statements if they are part of standard-setting organizations and to which standards they declare their patents. Furthermore, this thesis suggests that firms should distinguish patent that are unrelated, related or essential for standards. Investors value this information and could better predict what the future prospects of new products and technologies are. Based on the findings in this thesis, standard-setting organizations should be aware of the competition, contracts and patent law regulation within a standard. The findings implicate that firms could declare more essential patents to a standard than necessary for strategic reasons. Thus, firms could introduce essential patents to standards that have no adding value to standard-setting projects.

This paper has several limitations. First of all, this papers tests whether standard-related patents have a higher impact on the firm's performance than standard-unrelated patents. However, the number of matches obtained from the propensity-score matching model is too low. The logic behind this is that I match firms within the treatment group that operate in multiple standards in the same year, whereas the control group contains firms that only have one observation in a given year. This means that I match firms that are observable multiple times with firms that are only observable once in a given year. For this reason, it is not possible to find reliable and significant results whether standard-related patents receive a higher market value than standard-unrelated patents. Besides that, I do not compare citation-weighted standard-related patents with citation-weighted standard-unrelated patents. The reason for this is that the KPSS database only provides citation information for the patents that are filed before the year 2000. Besides that, the total numbers of essential patents that are declared to all standards per year are provided by the Searle Center database. For this reason, this thesis cannot distinguish whether declaring standard-essential patents to a specific standard has a better impact on the firm's performance than declaring standard-essential patents to another specific standard.

This study provides several recommendations for future research. The main recommendation for further research is to show whether standard-essential patents have a higher impact on the market value of a company than standard-unrelated patents. In order to succeed in this, researchers need a sufficient large dataset with similar firm characteristics to match firms within SSOs with firms that are not part of SSOs. Another recommendation for future research is to evaluate if patent citations of SSO firms lead to higher market value than patent citations of non-SSO firms.

Previous research already shows that patents that are part of standards receive twice as many citations compared to firms that do not participate in SSO's (Rysman and Simcoe, 2008). Further research could also indicate if this leads to a better firm's performance. Besides that, further research could evaluate whether different standard-setting organizations have a different impact on the firm's performance. Pohlmann et al (2011) find that there is a difference in firm's performance between firms that are part of informal or formal SSO, but there could also be a different impact of different formal SSOs on the firm's performance.

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8. Appendix

Table 9. Description of the variables of standard information database
This table gives a description of the variables that are used in this thesis from the Searle Center on Law, Regulation, and Economic Growth database. I divide the variables in different categories. First of all, the general variables of the database are described. After that, the information on standard-related innovation, the standard specific variables and the company specific variables are explained.

General

Variable	Description
Company	Name of the company
Company nr	Serial number (by company)
SIC	Standard industry classification (4 digits)
Year	Calendar year
Standard id	Name of the standard (on project level)
SSO	Identity of the SSO (main SSO if more than one)
Declaring firms	Number of declaring firms for this standard
Number firms	Number of firms in the sample for this standard

Information on standard-related innovation

Variable	Description
PAT	Number of standard-related patent files by a firm each year
CIT	Weighted by number of forward citations received within four years
SEP	Total number of declarations of standard-essential patents per year
IPC_g	Number of patent applications in the IPC category G per year. The IPC-G class is for telecommunication standards.
IPC_h	Number of patent applications in the IPC category H per year. The IPC-H class is for IT standards.
IPC_control	IPC_g for standards with ICS 33, IPC_h for standards with ICS 35

Standard specific variables

Variable	Description
Standard age	Age of the standard in years (zero in the year of first release, negative before)
St1-St26	Dummies for standard age
Pool memberships	Dummy indicating membership in one pool active on the main standard
Consortium memberships	Dummy (time-variant) indicating consortium membership of this firm this year
References cumulative	Number of forward references cumulative (per standard version)
Accreditations cumulative	Cumulative number of releases of equivalent standards at other SSOs
Version age	Number of years elapsed since last version release
Standard adoption	Number of mentions of the standard in news feeds per year

Company specific variables

Variable	Description
Employees	Number of employees
Lagged employees	One-year lag of employees
Sales	Total sales per year for each firm
Lag sales	One-year lag of sales
Rdexpense	R&D expenditures for each firm per year
Lag_rnd	One-year lag of R&D expenditures

Table 10. Description of the variables of the financial databases
This table describes the variables that are used from the COMPUSTAT Fundamentals Annual database and CRSP database. There are several variables described that are used to match the financial data with the standard information database. The other variables are used to calculate the dependent variables Tobin's Q and the ROA of a firm and are used to control for firm characteristics.

Variable	Description
CUSIP	Unique identifier for each North American company (9 digits)
GVKEY	Standard and Poor's identifier
PERMNO	Permanent security identification number assigned by CRSP
At	Total assets for each company
Ceq	Total common/ordinary equity for each company
Csho	Common shares outstanding per year
Ni	Net income (loss)
Prcc_f	Annual closing stock price for each fiscal year
xrd	R&D expense for each company per year
SIC	Standard industry classification (4 digits)

Table 11. Descriptions of Standard Setting Organizations
This table describes the purposes and responsibilities of all the SSOs that are used in this thesis. Furthermore, it provides some examples of the most important technologies that are developed by the standards in the SSOs. In this thesis there are seven different SSOs used to test the hypotheses.

SSO	Description
European Telecommunications Standards Institute (ETSI)	Standardization organization in the telecommunications industry. The ETSI provides every year globally between 2000 and 2500 standards for Information, Communication and Technology standards (ICT). The standards created key global technologies such as GSM cell phone system, 3G and 4G and smart cards.
International Telecommunication Union Telecommunication Standardization sector (ITU-T)	The main objective of the ITU-T is to coordinate the standards for telecommunications. The goal of the ITU-T is ensuring efficient and timely production of standards in the telecommunication industry. The international standards that are developed by the ITU-T are recommended standards. This means that they become mandatory if the national law adopts them.

International Electro technical Commission (IEC)	A non-governmental International organization that publishes standards for the electrical and electronic industry. The IEC manages three global conformity assessment systems that approve whether equipment, systems or components are conform to the international standards. Several technologies that are discovered by the standards of the IEC are power generation, semiconductors, solar energy and nanotechnology.
Institute of Electrical and Electronics Engineers (IEEE)	This organization is the largest organization with more than 400,000 members. The purpose of the IEEE is the educational and technical advancement of electrical and electronic engineering, telecommunications, computer engineering. The IEEE has over the 900 standards that operate in a wide range of industries, such as IT, telecommunications and transportation industry.
Joint Technical Committee of the ISO and IEC (JTC1)	The JTC1 develops, maintain and promote standards in the Information Technology (IT) and ICT field.
International Telecommunication Union Radio communication sector (ITU-R)	The ITU-R is responsible for developing standards in for the radio communication sector. The role for the ITU-R is to manage the International radio-frequency spectrum, satellite orbit resources and radio communication systems with the purpose of ensuring the effective use of the spectrum.
International Organization for Standardization (ISO)	This organization is the largest developer of voluntary international standards. Furthermore, by providing common standards between nations it facilitates world trade. There are more than 20.000 standards in the organization and those standards develop in every industry sector new technologies and products.

Table 12. Summary statistics of the standard-setting organizations
This table provides the summary statistics of standard-settings organizations in the sample. It describes the total number of firms that are part of the SSO, the total number of standards in the SSO, the number of pool members in the SSO and the number of consortium members in the SSO. This table is based on the number of cases that are used in the multiple regressions.

	ETSI	IEC	IEEE	ISO	ITU-R	ITU-T	JTC1
# Firms	17	1	30	1	14	25	25
# Standards	380	1	90	1	14	149	115
# Pool members	0	0	2	0	0	2	16
# Consortium members	6	0	44	0	0	9	30

Table 13. Standard Industry Classifications
This table divided the SIC codes of the companies in twelve main industries. This table also indicates the SIC code dummy that is created in the database.

SIC dummy	Range of SIC codes	Industry
1	0100-0999	Agriculture, Fishing and Forestry
2	1000-1499	Mining
3	1500-1799	Construction
4	1800-1999	Not used
5	2000-3999	Manufacturing
6	4000-4999	Transportation, Communications, Electrics, Gas and Sanitary service
7	5000-5199	Wholesale trade
8	5200-5999	Retail trade
9	6000-6799	Finance, Insurance and Real estate
10	7000-8999	Services
11	9100-9729	Public administration
12	9900-9999	Non-classifiable