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The propensity to patent an innovation in Japan:

A study of Swedish innovating firms' applications at the Japanese Patent Office, 1970-2015

by

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Abstract

Patents have long been considered an essential intellectual property mechanism in Japan. Foreign firms have simultaneously struggled with obtaining patents and market shares in Japan. Therefore, the incentives for Swedish innovating firms to patent their innovation at the Japanese Patent Office are plenty and can facilitate market integration. This thesis explores the historical development of Swedish innovating firms' patenting propensity at the Japanese Patent Office and aims to contribute to the debate on the role of patents for Swedish innovating firms if/when they are entering the Japanese market. The thesis utilizes patent-matched innovation data from the SWINNO-database over the period 1970-2015 and applies descriptive statistics, a decomposition analysis, and a logistic regression to examine the patent propensity. The results show that the propensity varies over time and across sectors. The probability of patenting is high in high-technology sectors and low for complex innovations. Two different patent trends are identified. The patenting practices increased during the first trend in the late 1970s and culminated in the early 2000s. The second trend began in 2002 and is characterized by a profound decrease in patent propensity. The results suggest that the incentive to patent an innovation at the Japanese Patent Office has declined since the early 2000s. This has implications for our understanding of the role of patents if/when a Swedish innovating firm is entering the Japanese market.

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List of abbreviations

ICT	Information and Communications Technologies
IP	Intellectual Property
JPO	Japanese Patent Office
LBIO	Literature-Based Innovation Output
R&D	Research and Development
SME	Small and Medium-sized Enterprises

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1 Introduction

Japan is Sweden's third largest export market outside of Europe as of 2020, and in 2018 the countries celebrated 150 years of diplomatic relations (Business Sweden, 2021). Both countries are also considered to be highly innovative, fostering innovative capabilities, and frequently topping the list of countries with the highest rate of patent applications per million inhabitants. Although trade and investment relations between the two countries are today strong, the Japanese market has historically been known to be difficult to penetrate for Swedish firms. Cultural and geographical distance is often pointed out as explanatory factors whenever this topic is discussed (Kviselius, 2008). Furthermore, it has historically been difficult for foreign firms to obtain a patent in Japan due to translation costs and other expenditures (Willquist, 2018). With the advent of globalization, appropriating the returns from innovation are imperative, and foreign patent application can offer the necessary protection.

The incentives for a Swedish firm to patent their innovation in Japan are plenty. One well-known example is Kid Cards, a Swedish innovating firm that developed a card-based game in 2004 (Näringsdepartementet, 2006). During the commercialization process, the firm encountered problems with declining sales, whereby negotiations on a license of the technology were initiated. A big Japanese corporation observed the unique feature of the innovation's technology and was initially interested in buying the product. However, since Kid Cards lacked a patent protecting the innovation, the Japanese firm concluded that the uncertainty of the deal was too high. The report from Näringsdepartementet revealed that the value of Kid Cards could increase tenfold if they owned a patent for the technology (Näringsdepartementet, 2006, s.191). This case shows that patents remain important for firms not only to protect their technologies but also to facilitate market shares and integration in the Japanese market.

1.1 Research Problem

This study notes that there are no comprehensive studies of Swedish firms' propensity to patent in Japan. Previous research on the propensity to apply for a patent in a foreign country shows that it is related to the peculiar features of the originating country, the technological closeness of the two countries, the economic involvement between the countries, and the harmonization of patent systems (Caviggioli, 2011). These factors pertain to increasing competition, risk of imitation, and market opportunities. Scholars have also linked innovations and patents to positive effects on the internationalization process and export market entry of firms (Cassiman & Golovko, 2011; Altomonte et al., 2014). The protection of intellectual property (henceforth IP) is a top priority for companies to appropriate the created value from their innovations. From a competition point of view, increased market shares are not driven only by price competition but also technology competition. A firm has in theory bigger chance of making it on an international market if they patent their innovation in another country's patent office (Frietsch et al., 2014). This hypothesis is supported by a study conducted by Neuhäeusler (2012) which found that internationalized firms tend to utilize patents as basic requirements for entering foreign markets. Moreover, previous research has shown that the use of patents in Japan is more significant than in the US and remains an important channel for research and development (R&D) flows, cross-licensing, and negotiations (Cohen et al., 2002). In addition, Granstrand and Holgersson (2012) have proposed that a "pro-patent" era emerged in the late 1980s. The pro-patent era marks the beginning of a worldwide pro-patent era initiated by Japan and the US. During this period, the number of patent applications increased significantly internationally.

However, no prior research has been conducted on Swedish innovating firms' propensity to patent their innovations in Japan. Patents have long been recognized as an essential IP protection mechanism in Japan, and foreign firms have simultaneously struggled with obtaining market shares and patents in Japan. Therefore, a study on Swedish innovating firms' patent activities at the Japanese Patent Office (henceforth JPO) can shed light on these patterns and developments.

1.2 Purpose of research

From this standpoint, this thesis aims to conduct an in-depth study of Swedish innovations patented in Japan. The aim is to provide knowledge about the historical development of Swedish innovating firms' patenting activities at the JPO and contribute to the debate on the role of patents for Swedish innovating firms if/when they are entering the Japanese market or conducting business with Japanese firms. The thesis will discuss how patenting behavior has evolved over time and analyze the characteristics of these patented innovations. This includes an analysis of the novelty and complexity of the patented innovations and the sectoral propensity. It also involves a comparison of the findings with industry sectors that have high economic involvement with Japan. The present analysis covers the period 1970-2015 across all sectors in the Swedish manufacturing industry and Information and Communications Technologies (henceforth ICT) services. The thesis also intends to analyze potential factors behind the patent trends and discuss the implications of the patterns. Potential factors comprise events that could have had an impact on the patent propensity, such as changes in the patent framework with the emergence of a pro-patent era and the amendments to the Japanese patent laws. The pro-patent era was preceded by several amendments to the Japanese patent law. Patent reforms in 1975 and 1988 made the law more internationally harmonized and increasingly easier for a foreign firm to patent in Japan. Therefore, the amendments to the patent law will be discussed in relation to the findings.

The innovation data used for this thesis were obtained from SWINNO – an unprecedented database of Swedish innovations that covers the period 1970-2019 (Sjöö et al., 2014). SWINNO has recently been updated with manually and machine-learning matched patent data derived from Google Patents (Johansson et al., 2022). In order to conduct this study, the thesis employs descriptive statistics, decomposition analysis, and regression analysis to analyze the propensity to patent.

1.3 Research questions

For the purpose of this thesis, the following research questions were formulated:

1. *How many Swedish innovations were patented in Japan during the period 1970-2015?*
2. *What trends are there in the propensity to patent in Japan among Swedish firms?*
3. *What types of innovation tend to be patented in Japan?*

1.4 Outline of the Thesis

The remainder of this thesis is organized as follows. Section 2 provides a contextual background to important aspects related to the aim of this thesis. Section 3 reviews literature on the concept of innovations and different approaches to measuring innovations and patent propensity. The section also discusses possible explanatory factors that can affect the probability of applying for a foreign patent. It ends with a discussion on the concept of a pro-patent era. In section 4, key concepts and theoretical implications derived from the literature review are summarized and corresponding hypotheses are introduced. Section 5 examines the data and method used for the purpose of this thesis. Section 6 and 7 report the empirical results of the study and presents a conclusion and suggestions for future research.

2 Background

This section gives a contextual background to important aspects related to the thesis. As pointed out in the introduction, aspects such as the economic involvement between the countries, and the harmonization of patent systems are important aspects that can affect the propensity to patent at a foreign patent office (Caviggioli, 2011). Therefore, in this section, the historical development of the Japanese patent law since the 1970s is described. The section also intends to give examples of sectors in the Swedish industry that have historically been exposed to competition from Japan. The section ends with a historical overview of changes in Japan's trade policies and the development of Sweden's export to Japan since the early 1990s.

2.1 The Japanese patent system

The JPO played a prominent role during Japan's catch-up phase, from the 1950s to the late 1970s, and IP rights became a general means for creating a resilient national innovation system (Granstrand, 2016). During this period, a prominent patent culture was established among Japanese corporations that embodied distinct patent practices and management. However, the Japanese patent law has been amended on several occasions over the last three decades.

The first big amendment was ratified in 1975, but the one in 1988 made substantial changes to the system. The demand for these reforms initially came from foreign firms, almost exclusively US trading partners, aiming to harmonize the patent system between the countries. The pre-amendment system only permitted one independent claim with a disreputable narrow scope (Sakakibara & Branstetter, 1999). In practice, this meant that more patents had to be filed in Japan to protect the same innovation. Because of this cumbersome process, the system was often called the *sashimi* system, referring to the Japanese sliced fish dish (Sakakibara & Branstetter, 1999).

The law proved to be problematic for US firms, as the single claim system could expose an invention to protection weakness often exploited by Japanese firms – a Japanese firm could identify "holes" in a firm's patent portfolio and file patents closely related to the technology. This practice is called "patent flooding". Therefore, the reforms ought to improve the conditions by expanding the scope, allowing for the inclusion of several claims in one patent.

Scholars have discussed the Japanese patent system during the 1980s and 1990s, arguing that foreign applicants faced longer pendency periods compared to domestic applicants (Kotabe, 1992). However, other researchers claim that the issues were not of a discriminating nature but a consequence of insufficient understanding of the Japanese perspective on patents and business affliction (Wineburg, 1988). Nevertheless, in response to growing critique and pressure from the business sector, the Japanese government amended the law again in 1994, 1998, and 1999, changing the pre-grant opposition system to a post-grant opposition and strengthening the patentee in patent litigation cases (Nagaoka, 2009). The structure was even more harmonized with the enactment of the Basic Law on Intellectual Property in 2003, and the establishment of the Intellectual Property High Court in 2005. Previous research has concluded that the overall demand for reforms should be viewed from the perspective of globalization and the emergence of a knowledge-based economy (Näringsdepartementet, 2006, p. 156). The TRIPS Agreement and the Lisbon protocol are examples of an aim toward comprehensive and global patent regulations. Patent data from the JPOs website in Figure 1 shows that the amount of granted patents at the Japanese patent office by Swedish firms has since 2005 increased tremendously, while the number of applications decreased between 2007 and 2015.

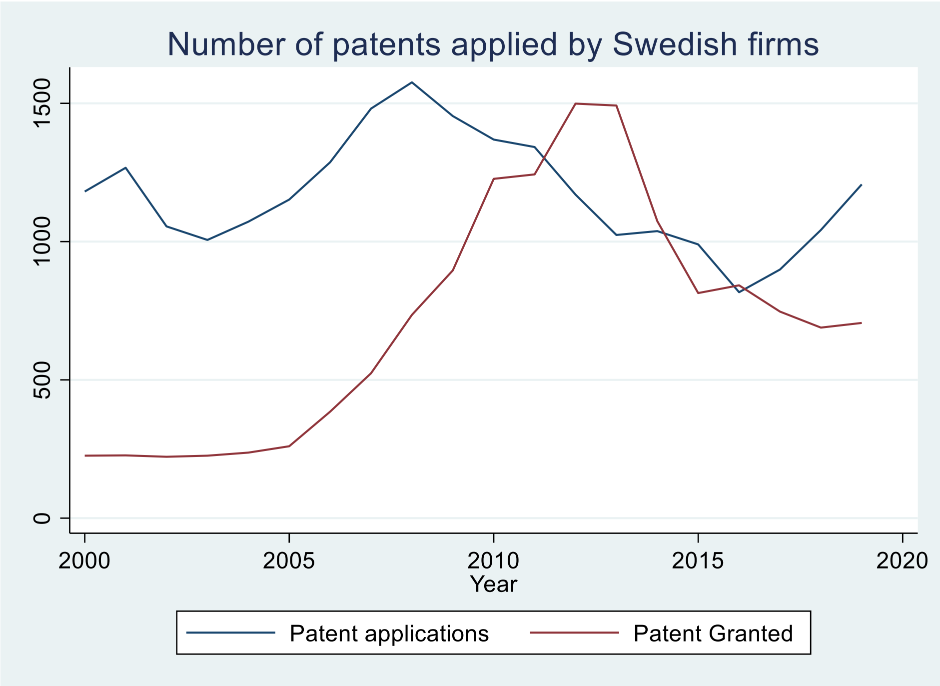

Figure 1 Patents filed by Swedish firms at the JPO 2000-2018

Source: (The Japanese Patent Office, 2022)

2.2 Competitive industries

There are examples of sectors in the Swedish industry that have historically been exposed to competition from Japan. During the 1980s, Japan had forged ahead in technological development in an emerging knowledge-based economy, and this was perceived as a threat by the US (Näringsdepartementet, 2006). Japan gained success in the ICT sector, which also spurred its Swedish counterpart to invest more and stay competitive. For example, *the Japanese Fifth Generation Computing Project,* a project initiated and funded by the Japanese Ministry of International Trade and Industry in 1982, was developed to raise technological capabilities in computing and establish Japan as a forerunner in electronic industries (Myers Jr & Yamakoshi, 2020). The response from Sweden came with the establishment of the *Swedish Institute of Computer Science* in 1985.

Despite fearing for Japan's growing success, Japanese dominance in the ICT sector never materialized. Japan was struck by a long economic recession in 1991 (Hayashi & Prescott, 2002). This has sometimes been called "the lost decade" of the Japanese economy. The economic crisis weakened innovation capacity as Japan suffered a marked decline in research performance compared to international standards (Yamashita, 2021). The innovativeness in the ICT sector was particularly affected. Although Japan's capabilities in the ICT sector remained high, the investment in ICT stagnated during this period (Fukao et al., 2016).

The Swedish ICT sector experienced the opposite development. Albeit Sweden entered a similar economic crisis in the early 1990s, the number of ICT innovations increased rapidly over the next decennium. One study has noted that the surge in ICT innovations came in two different surges (Taalbi, 2018). The first surge occurred in the midst of the structural crisis in the 1970s and the bulk of these ICT innovations were designed for industry automation and developed by larger firms. A second surge came amid the 1990s crisis. These ICT innovations were predominantly commercialized by smaller firms and within sectors such as telecommunication, software, and micro-electronics.

The electronic industry was not the only sector exposed to Japanese competition during the 1980s. The Swedish machinery sector had difficulties coping with growing competition from Japanese machine tool firms beginning in the early 1970s. The development of microcomputer CNC (computer numerical control) units was initiated by the Japanese firm Fujitsu Fanuc during the 1970s, which gave Japanese firms a comparative advantage over Swedish firms (Ehrnberg & Jacobsson, 1993). Japanese firms succeeded in introducing new markets and grew significantly with the diffusion of these new technologies. Many Swedish firms that produced numeric controlled machines were heavily export-oriented and were forced out of business in the 1990s by Japanese rivals (Taalbi, 2014, p. 158).

2.3 Japan's import expansion

The Japanese patent system was not the only segment that gained criticism from the U.S during the 1980s. Trade friction between the countries had intensified over the period due to Japan's large trade surplus (Abe, 2017). The pressure to open the Japanese market to foreign firms and remove trade barriers and tariffs eventually led to what is referred to as an "import expansion policy" in the late 1980s. New trade policies coupled with a drawn-out economic downturn in the 90s transformed the Japanese trade structure substantially during the early 1990s. Consequently, real imports rose sharply. Kozu et al. (2002) point out that this was especially the case for IT-related goods and consumer goods. The IT sector could take advantage of an increasingly globalized world economy and the move towards global fragmentation in trade goods. The result of the import expansion policy is significant if we look at Sweden's export to Japan between the years 1992 and 2018 (see figure 2). Sweden's total export to Japan increased tremendously between 1993 and 1996.

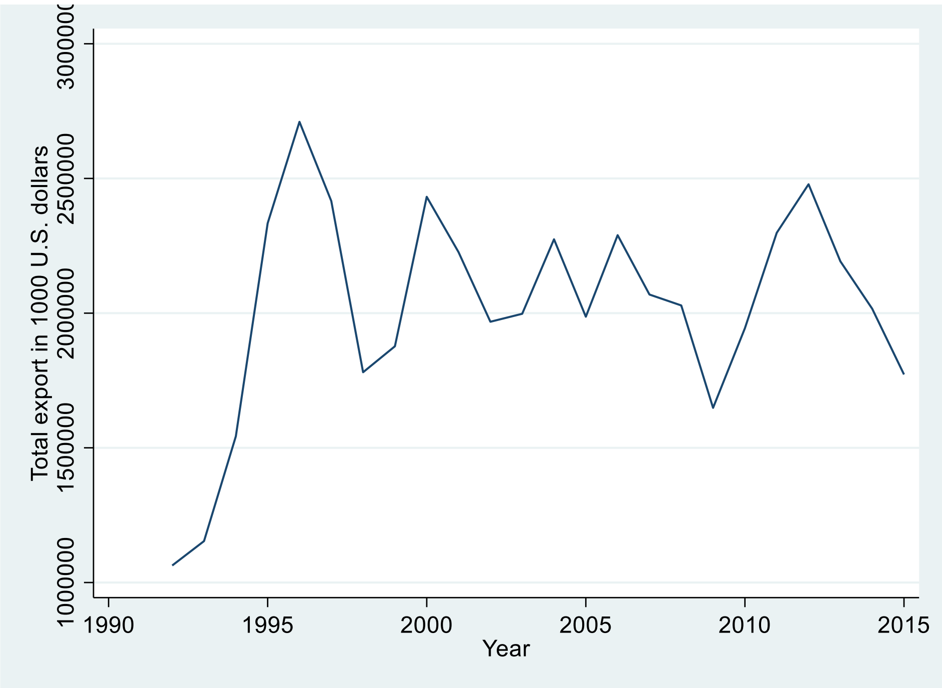

Figure 2 Sweden's export to Japan 1992-2018 in current prices

Source: Trading Economics (2022)

However, the export to Japan has been somewhat lower since the dot-com crash in the early 2000s. Using the recent available data from Trading Economics (2022), the author of this thesis has analyzed the export to Japan between 1992-2018 by sector and identified the ten largest export sectors in figure 3. These are sectors with high economic involvement with Japan. Sectors below the threshold of 1% of the export share have been registered as "other". The data used in this thesis starts with the years 1992 and onwards as the available data from Trading Economics are limited to these years. The biggest contributor to the export expansion during the 1990s was electrical and electronic equipment (see figure 3). On a sectoral level, it dominated the export to Japan until the early 2000s. The dot-com crash hit the sector hard, and although it remains an important contributor, it has not regained its past dominance. The increase in ICT exports during the 1990s coincides with a domestic stagnation in the ICT sector in Japan and the surge of ICT innovations developed in Sweden. The most prominent change since the early 2000s is the steady increase in exports from the pharmaceutical sector. This indicates that the pharmaceutical industry has become an important export sector to Japan.

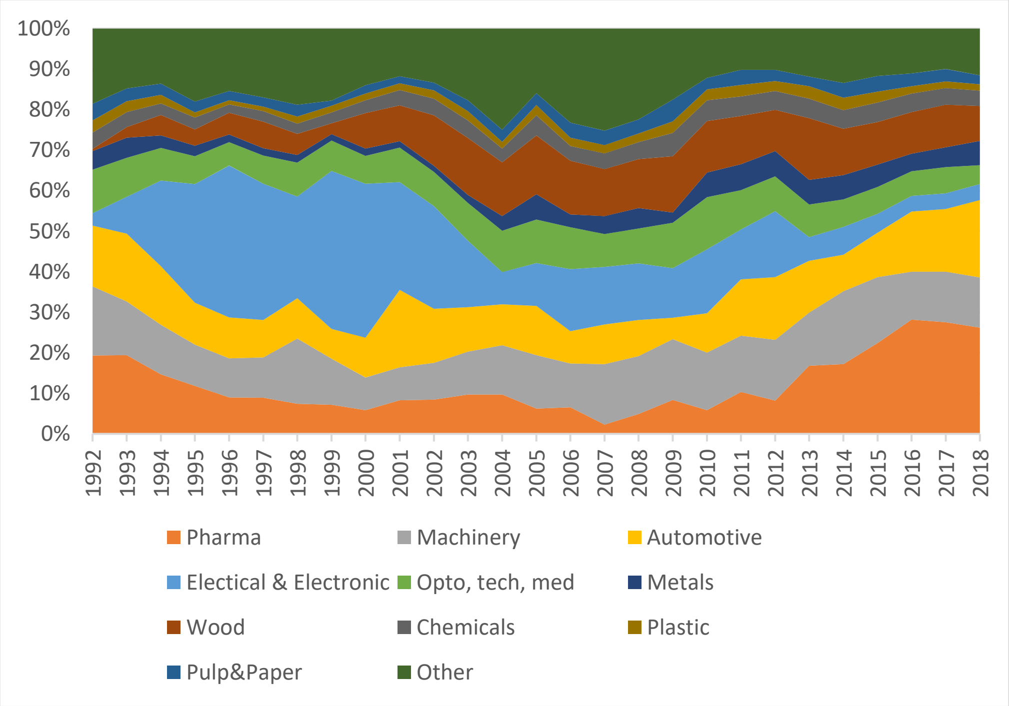

Figure 3 Sweden's export to Japan by sector 1992-2018 in current prices

Source: Trading Economics (2022)

With this background, we have discussed important aspects that can affect the patenting behavior of Swedish innovating firms. They include the amendments to the patent law, examples of sectors exposed to competition from Japan and the recent developments in the Swedish export sector to Japan. These aspects will be included in the discussion.

3 Literature review

This section reviews previous research on the concept of innovations and different approaches to measuring innovations and the patent propensity. This is followed by a summary of previous research about explanatory factors behind foreign patent applications. The section ends with a detailed description of the "pro-patent era" as defined in several studies.

3.1 The concept of innovation

To discuss the propensity to patent an innovation, it is pivotal to define the concept of innovation and how patents relate to innovations. In the field of innovation studies, an innovation has been understood as a driving force behind long-run economic growth and technological change. Researchers often distinguish an *invention* from innovation (Fagerberg et al., 2005). Invention is the first occurrence of an idea for a new product or process. Innovation concerns the process in which an economic agent exploits an invention to create value. This definition lies close to the Schumpeterian rigorous view that innovations "…combine factors in a new way, or that it consists in carrying out New Combinations…" (Schumpeter, 1939, p. 84). He argues that an idea or a scientific principle (invention) has no economic importance by itself. The potential instead lies in the exploitation of an invention in an economic context. Schumpeter's definition of new production function covers the commercialization of a new commodity, the creation of new markets, new form of organization and development of new materials (Schumpeter, 1939, p.84). In addition, an economic agent needs to allocate resources, such as production knowledge and facilities, to transform an invention into an innovation. These economic agents, famously referred to by Schumpeter as "entrepreneurs", are consequently important for economic growth and technological change.

Scholars in innovation studies usually differentiate between product and process innovations (OECD & Eurostat, 2018). An innovation can either *create or improve* products (product innovations) or improve the production by introducing new technologies (process innovation). Thus, an innovation can both be tangible products and intangible assets. Moreover, although a given innovation is perceived as a continuous process built on previous innovations, an innovation can be classified by how radical they are in relation to existing technologies (Fagerberg et al., 2005). According to this view, an innovation is either *incremental* or *radical*. An incremental innovation is an improvement to already existing technologies. A radical innovation exploits disruptive technologies that can have profound societal impact. However, it is widely believed that the cumulative impact of incremental innovations can be even greater than radical innovations, especially since radical innovations often require complementary technologies to achieve its potential (Fagerberg et al., 2005).

3.2 Measuring innovations

This study investigates the propensity of innovations to be patented. Hence, we need both a measure of innovations and a measure of patents. In the field of innovation studies, measuring innovations has been notably difficult, and researchers have constructed different approaches over the years. This is also pointed out as a major reason why studies have arrived at different results (Kleinknecht et al., 2002). One of the most popular approaches is the use of patents (Nagaoka et al., 2010). Patent indicators measure innovations by firms' tendency to engage in the development of new technologies by looking at IP protection. This approach remains popular among researchers due to the easy access to available data and the abundant information on the flow of technology capabilities provided by patents and patent citations. However, the downside of patents is well known. Patents are foremost an invention indicator and do not measure innovation activity. Fontana et al. (2013, p. 1782) noted this with the comment that not all inventions are commercialized, and not all innovations are patented. Therefore, using patents as an innovation indicator has its limitation and can be misleading.

An alternative approach that has garnered interest is the innovation output indicator (Bain & Kleinknecht, 2016). This approach is subdivided into two different methodologies: subject-based output and object-based output. A subject-based approach collects innovations by interviewing agents involved in the innovation process. A common way to perform a study with this approach is through firm surveys (Brouwer & Kleinknecht, 1999). The other methodology, the object-based output model, collects data either by interviews with industry experts or by reading trade journals (Ikekuchi, 2017; Fontana et al., 2013). SWINNO, the database used for this thesis, applies an object-based output method, namely Literature-Based Innovations Output (Sjöö et al., 2014). This method will be thoroughly discussed in section 5.

3.3 Patent propensity

As established in the previous section, a patent does not necessarily lead to innovation. Consequently, scholars have sought to clarify to what extent innovations are patented by measuring the propensity to patent among innovating firms. There exist numerous ways to measure patent propensity. One approach adopted by researchers is the patent per R&D cost ratio (Scherer, 1983). This model measures the ratio between the patenting intensity and the R&D intensity on a sector level and firm level. A second approach is to measure the share of patented innovation to the total number of innovations commercialized over a certain period (Fontana et al., 2013). The latter approach is adopted for this thesis and will be discussed in section 4.

Studies in patent propensity have produced widely varying results (Fontana et al., 2013; Cohen et al., 2000; Arundel & Kabla, 1998; Brouwer & Kleinknecht, 1999). While the result from Fontana et al. only amounted to 9.6%, Cohen et al. found the propensity to be approximately 49 %, Brouwer and Kleinknecht calculated it to be 25.4%, and Arundel and Kabla roughly estimated it to be 36%. The rather large spread in the results could partially be explained by the method used. Cohen et al., Brouwer and Kleinknecth, and Arundel and Kabla apply similar approaches: Cohen et al. use a survey questionnaire in the US manufacturing industry in 1994, while Arundel and Kabla analyzed a 1993 PACE survey, and Brouwer and Kleinknecht used CIS Survey. Fontana et al. chose a different method by matching innovation data[1] from the journal *Research and Development* with patents from the United States Patent and Trademark Office.

[1] The innovation data was selected from winners of the R&D 100 awards competition launched by the journal

Previous research have also shown that the propensity varies across industries (Arundel & Kabla, 1998; Fontana et al., 2013). The reason for this is the value of patents as a means for appropriating the investments in R&D and innovations differ. Previous research has concluded that most firms tend to prioritize the use of other IP protection mechanisms, such as lead time advantages and secrecy (Cohen et al., 2000). Sectors such as machinery, R&D and pharmaceuticals have in general high propensity since the cost of copying are less than the initial cost of developing innovation. Sectors where patenting is not considered a particularly valuable appropriability model include software, rubber, textiles, and basic metals. A study by Chabchoub and Niosi (2005) has shown that the propensity in the software industry, 13%, is low compared to other high-technology industries. However, the sector's propensity has increased since the 1990s and this is explained by the fact that software patents have become more cost-effective over time.

Arundel and Kabla (1998) also claim that patenting is a less relevant protection mechanism for complex innovations. Complex innovations consist of many technological elements and therefore costly and difficult to copy. The high artefactual complexity makes copying time-consuming. Other barriers include high investment barriers and the need for trained experts. Instead, innovating firms tend to adopt alternative appropriability strategies to protect a complex innovation, i.e., lead time and secrecy.

3.4 Foreign patent applications

The relation between innovation and internationalization has been widely discussed and analyzed (Castellani & Zanfei, 2007). Kviselius (2008) remarks that internationalizing has become more important for firms to gain advantages in a globally competitive environment. Previous research have claimed that innovation can be a key driver in the internationalization process and export market entry of a firm (Altomonte et al., 2014; Cassiman & Golovko, 2011). An innovation can in these cases create a niche for the firm to establish itself on the market. Patents can form the basis of an innovation's IP protection and can be used by firms in several strategical ways: to facilitate market access and integration, or initiate negotiations or license agreements with competitors and other commercial actors. According to Neuhäsler (2012), internationalized firms tend to use patents as a basic requirement for entering an international market and maintaining market shares. Frietsch et al. (2014) find a strong correlation between export and patents, especially in high-technology sectors. They argue that patent applications are a strong predictor of export activities from the theoretical view of competition. A lasting development in market shares is not only driven by price competition but also technology and quality competition. Hence, a foreign patent application can raise market opportunities in international trade.

Caviggioli has compiled several factors that theoretically could affect a firm's propensity to apply for a patent in a foreign country: the peculiar features of the originating country, the technological closeness of the countries, the economic involvement, and the harmonization of patent systems (Caviggioli, 2011, p. 161). The peculiar feature of the originating country involves the inventiveness of the country, the cultural institutions, and the GPD per capita and size. With technological closeness, Caviggoli argues that if two countries share specialization in certain sectors, the technological barriers to copying an innovation are comparatively low (Caviggioli, 2011). Therefore, the incentive to patent will increase to protect technological capabilities from foreign competition. The economic involvement factor concerns the export market and foreign direct investments. With high export shares, many technologies will be transferred, which require high IP protection. Without proper IP protection, it can cause significant damage to the commercial interest if the other country manages to copy the firm's technological capabilities. Lastly, the harmonization of patent systems has the potential to decrease patent fees and other expenditures linked to a patent application. If the protection of IP is similar between the countries, the propensity will likely increase due to the harmonized legal institutions.

3.5 A pro-patent era

As mentioned in section 2, patent-related issues between US and Japan were resolved by patent reforms and international harmonizing of patent systems. Consequently, the number of patent applications increased significantly worldwide. This phenomenon was defined by Grandstrand (2016) as a pro-patent era. The pro-patent era affected technology and patent management significantly among Swedish firms (Granstrand & Holgersson, 2012). A study on patenting behavior among Swedish firms conducted by IVA/PRV[2] in 1992-1993 had a particular impact. The study became a benchmark in the Swedish industry. Key issues in the study pertained to the difference between big firms in Sweden and Japan – Japan was referred to as the “best practice” when it came to patenting strategy and management (Näringsdepartementet, 2006, p. 153). It showed that patents had become increasingly important and that patent management among big firms in Sweden lagged behind Japan. These statements had an immediate effect; the patent awareness and patent propensity increased drastically during the early 1990s. Granstrand and Holgersson commented on this development with a laconic remark: “There is no way to fight a patent but with a patent” (Granstrand & Holgersson, 2012, p. 24).

Granstrand and Holgersson (2012) also found that a deviation from the pro-patent trend occurred in 1992. This coincided with the financial crisis in Sweden, but the break did not have a long-term effect. The propensity increased during the rest of the 1990s. However, a big trend break happened in 2001 with the burst of the dot-com bubble. The Swedish industry experienced a prolonged decrease in propensity rate. Granstrand and Holgersson have investigated the reasons behind this break. Based on questionnaire surveys among Swedish firms, they claim that the patent propensity decreased around the dot-com crash and the focal reasons for this are lower R&D resources among firms and a shift towards more selective and qualitative patenting strategies (Granstrand & Holgersson, 2012, p. 14). This was true regardless of the size of the firm. While the propensity decreased on an aggregated level, firms simultaneously began to recognize the importance of patents. A so-called “quality oriented pro-patent strategy” emerged (Granstrand & Holgersson, 2012, p.25). The result was a shift towards applying for fewer patents but more effective and cost-saving ones. Firms simultaneously began to internationalize their IP operation with applications filed at the Patent Cooperation Treaty (PCT). The outcome is fewer national applications and a turn towards a globalized patent regime (Granstrand, 2016).

[2] Royal Swedish Academy of Engineering Sciences and the Swedish Patent and Registration Office

4 Analytical framework

This section leverages the previous literature review to make hypotheses about trends in patenting activities over time and across sectors. But first the definition of patent propensity used in this thesis needs to be addressed. As discussed in the preceding section, previous research on patent propensity has generated a wide range of results. The reason for this is the lack of an established methodology. However, this thesis adopts a definition of patent propensity as put forward by economic historians and historians of technology. This framework defined patent propensity as "…the share of patented innovations in the total number of innovations occurring in a given time period" (Fontana et al., 2013, p. 1781).

In light of the reviewed literature, the author of this thesis has constructed five hypotheses. First, the harmonization of patent systems has been highlighted by researchers as being an important factor behind the propensity to patent at an foreign patent office (Caviggioli, 2011). The Japanese patent law has been revised on several occasions and become increasingly internationally harmonized since the 1970s. The multiple claim system adopted in 1988 gave foreign firms the opportunity to save patent-related fees, as the number of required patents were reduced (Sakakibara & Branstetter, 1999). The amendments to the patent laws are part of a turn towards international pro-patent policies initiated by the United States. The pro-patent era emerged in 1985, and intensified in Sweden with the IVA/PRV study in 1992/1993 (Näringsdepartementet, 2006). Moreover, the propensity to patent in Sweden has shifted towards a more selective and qualitative patent approach since the early 2000s (Granstrand & Holgersson, 2012). Thus, this gives us the first and second hypothesis:

H1: *The propensity to apply for a patent will increase with the harmonization of the Japanese patent laws and the emergence of a pro-patent era.*

H2: *The shift towards a selective and qualitative patenting in the early 2000s will decrease the propensity to patent.*

Previous research have asserted that the propensity differs across industry sectors (Chabchoub & Niosi, 2005; Arundel & Kabla, 1998). Sectors that generally are considered to have low patent propensity includes software, textiles, and basic metals. Industries with high propensity include R&D, machinery, chemicals, and electronics. This gives rise to the third hypothesis:

H3: *The patent propensity is expected to be higher in high-technology sectors and increase more in these sectors during the pro-patent era.*

Finally, the complexity of the innovation will affect the propensity. As discussed in section 3, patents are less valuable as a mean of appropriating innovation investments for complex products (Arundel & Kabla, 1998). Therefore, the fourth hypothesis is:

H4: *The propensity to patent will change depending on the artefactual complexity of the innovation.*

As proposed by Caviggioli (2011), the propensity apply for a foreign application are driven by macroeconomic and structural characteristics. Research has shown that patents are important to raise the firm value, trustworthiness, and security (Neuhäusler, 2012). In addition, Japan developed a well-established patent culture among their corporation, and Japanese firms have historically taken advantage of their patent system and used strategic patent flooding. This indicates that Swedish firms will experience disadvantages in market shares, negotiations, and license agreements if they do not patent their innovation in Japan. This thesis has identified ten of the largest export sectors to Japan in section 2.3 and these sectors will be analyzed in relation to the results presented in section 6. Therefore, the thesis posits the final hypothesis:

H5: *The patent propensity is expected to be higher in sectors that have high economic involvement with Japan.*

5 Methods and data

5.1 Data

This subsection introduces the data used for this thesis. First, it discusses the approach of LBIO, and the innovation data derived from SWINNO. Second, it examines the innovation-patent data matching process. It ends with a discussion on the limitation of this data.

5.1.1 The SWINNO database

As mentioned in the introduction, the innovation data used in this thesis was taken from the SWINNO database. The database was constructed in the years 2008-2014 and is a rich source of data on innovations commercialized by Swedish manufacturing firms (Sjöö et al., 2014). The innovations are gathered by using an object-based innovation output method called *Literature-Based Output Indicator* (henceforth LBIO). The approach to LBIO involves screening fifteen industrial periodicals and collecting journal articles covering the manufacturing industry and ICT services. The database is updated annually and at the time of writing includes the years 1970–2020. The screenings have captured over 4700 innovations and 8000 journal articles.

The LBIO-method provides several advantages, such as the potential to construct a longitudinal innovation database with consistent and detailed information on all the gathered innovations (Sjöö et al., 2014) The database encompasses a broad range of innovation variables collected from the journal articles. The basic variables include a technological description of the innovation and the name of the innovating firm, innovators, and contact persons, viz., the subjects of the innovation process. The database also registers variables important for this study: the novelty of the innovations, the complexity of the innovations, and the industry sector producing the innovation. The access to this data allows for both qualitative and quantitative analysis in innovation studies.

An innovation is selected based on three inclusion criteria:

1) The innovation must be on the market or in the process of being commercialized.
2) A commercial agent must be identified - a "orphan" innovation without an innovating firm is therefore excluded.
3) Only product innovations are registered. A product innovation is defined as a product, process or service that are being sold or in the process of being sold on the market
4) The novel feature of the innovation must be explicitly stated (Taalbi, 2014, p. 63).

5.1.2 Matching patents to SWINNO-innovations

The SWINNO database has recently been matched with patent data extracted from Google Patents. Google Patents is a database indexing patents and patent applications from patent offices all over the world (Johansson et al., 2022). By linking SWINNO-innovations with patents retrieved from Google Patents, the project has generated data on the propensity to file a patent application among SWINNO-innovations over the period 1970–2015. The purpose is to highlight what LBIO as an innovation indicator captures as opposed to the use of patents as innovation indicators. As discussed in the literature review, patents have their strengths and weaknesses, and this project has furnished more data on this matter. The project also indents to contribute with in-depth knowledge of patent trends among SWINNO-innovations and the characteristics of these patents. Taalbi (2022) discusses general patterns of patenting using this novel data. This thesis focuses on Swedish firms' patent activities in Japan.

The patent matching was performed in the years 2019-2022 and consisted of two stages. First, SWINNO-innovations developed by small and medium-sized enterprises (SMEs) were manually checked. The author of this thesis conducted the majority of the manual checking. The screening was done by searching in Google Patents on information on each innovation provided by the innovation articles. This includes the name of the inventor, innovating firm, or the contact person. The manual checking was limited to SMEs due to their tendency of developing innovations with low or medium complexity; these innovations usually consist of a few patentable elements. SMEs also have smaller patent portfolios and usually only obtain one or two patents during their lifetime. Hence, evaluating each patent's relevance was deemed feasible. Approximately 3600 innovations were manually checked, counting both non-patented innovations and patented innovations. For a patent to be identified as a match, it needs to meet the following criteria:

i. The patent must be directly related to the innovation and/or the novel feature of the innovation, as described in a text.
ii. The patent document must contain a description (not just a title) linking the patent to the innovation.
iii. The patent needs to be filed within ten years before or after the commercialization year (Johansson et al., 2022, p. 2).

However, big firms and innovations with high innovation complexity, composed of many patentable parts, proved to be more difficult for manual checks. A few big innovating firms, such as ABB and Ericsson, each have over 135000 patent applications registered in Google Patents. The manual screening of these innovations was assumed to be too work extensive. Consequently, a second methodology was devised to ensure consistent and robust data collection. This second stage consists of keywords, web scraping, and machine learning (see Johansson et al., 2022, for more information about the machine-learning method). A subset of innovations was selected based on the size of the firm, its patent portfolio, and innovations complexity. The subset includes big firms with over 200 patent applications and complex innovations, e.g., pharmaceuticals. Then, keywords were extracted from the innovation articles and applied for the matching process of a patent and an innovation. The results from the manual matching and the machine learning matching are presented in Taalbi (2022). This thesis presents an addition to this work, delving into the trends and patterns in the Swedish innovating firms' propensity to patent at the JPO.

5.1.3 Limitations

There are some obvious limitations to the use of LBIO as innovation indicator that needs to be addressed. As aforementioned, the scope is constrained to the judgement of selected industrial periodicals and these periodicals need to explicitly mention the innovation's novelty and significance for an inclusion. Consequently, only significant innovations are collected. Furthermore, as SWINNO solely captures product and process innovations, this implicates that other innovation types, e.g., service innovations or organizational innovations, are underreported. Because of this limitation, the collected data do not reflect all types of innovations.

Regarding the patent matching methodology, there are some issues that needs to be addressed. The main issue to deal with is how well the matching process has been performed. This concerns both the manual matching and the machine learning process. The manual process adopts a textual comparison of patent texts and innovation articles. It needs to provide a patent abstract or a description linking the patent to the innovation to comply with the matching criteria. Therefore, there exist a possibility that relevant patents that lack these criteria are disregarded. One other caveat is the spellings of the innovating firm and inventors. The letters [å], [ä] and [ö] in the Swedish alphabet are often converted to [o], [ae] and [oe] in Google Patents. The different spellings affected the search result, so there is a possibility relevant patents have been overlooked.

The machine learning method also has some drawbacks. Since the machine learning method derives the matched patents from patent texts and abstracts, the issue lies in how well the matching responses to the patent texts. Patent terminology is often technology-specific and must comply with different industry requirements. Hence, the semantic use of keywords will vary across patent texts and industry sectors. However, this issue has been mitigated by manually analyzing roughly 2000 machine-matched patents which amounts to 15 % of all the patents. The aim was to assess the status of these patents and has generated more robust data.

5.2 Methods

This subsection describes the methods used for the purpose of this study. As mentioned before, the thesis applies both descriptive statistics, decomposition analysis, and logistic regression analysis. The first research question measures the patent propensity among SWINNO innovations and therefore, the propensity equation will be discussed below. Descriptive statistics were used for the thesis' first and second research questions. The decomposition analysis is applied to the second research question. The regression analysis addresses the second and third research questions and is also introduced here.

5.2.1 Patent propensity

As defined in the theory section, the patent propensity is the share of patented innovations to the total number of innovations commercialized over a given period. The given period is the commercialization year and the equation for the patent propensity (P_t) is the following:

$$P_t = \frac{\alpha_t}{\alpha_t + \upsilon_t} \qquad (1)$$

where α_t is the number of SWINNO-innovations matched with patents derived from Google Patents for a certain year; υ_t stands for the number of non-patented SWINNO-innovations for the same year. For example, in 2004 the number of patented innovations were 35, while the number of non-patented innovations mounted to 45. This means that the patent propensity for the year 2004 is roughly 44%.

5.2.2 Decomposition analysis

The composition of changes in the patent propensity can vary depending on what drives different sectors to patent their innovations. For example, changes can happen as growing sectors also expands their propensity (a so-called “interaction effect”). The propensity can also expand or decrease as sectors with high patent propensity increases their innovation level (a so-called “between effect”). Lastly, changes can also occur as the propensity changes across all sectors (a so-called “within effect”). An analysis of the composition of the changes is crucial. Therefore, following the analysis procedure of Taalbi (2022), this thesis will carry out a decomposition analysis. This is done by studying the composition of the average percentage point change in the patent propensity *($\overline{p}$)* in the three components mentioned: the interaction effect ($\sum_i \Delta\rho_i \Delta s_i$); the between effect ($\sum_i \Delta\rho_i s_i$); and the “within effect” ($\sum_i \Delta s_i \rho_i$). Thus, the equation is the following:

$$\Delta\overline{p} = \sum_i \Delta\rho_i \Delta s_i + \sum_i \Delta\rho_i s_i + \sum_i \Delta s_i \rho_i \quad (2)$$

The result from this analysis is presented in section 6.

5.2.3 Logistic regression

For the regression analysis, the dependent variable – the propensity to patent in Japan among Swedish innovations – is dichotomous as it distinguishes two states: either the innovation is applied for a patent in Japan, or it is not. For that reason, the most suitable model is logistic regression, as this model tells us about factors that influence the probabilities of an innovation being applied for a patented in Japan. Consequently, the thesis will apply a logistic regression model to discuss probabilities based on variables collected from the SWINNO-database. This model is applied for the thesis' second and third question: *What trends are there in the propensity to patent in Japan? What type of innovations tend to be patented in Japan?*

From the literature review, the thesis has identified a range of important variables that can affect the propensity to apply for a patent at the JPO. These include the industry sectors, the novelty of the innovation, and the complexity of the innovation. The amendments to the patent law in 1975 and 1988 are additional variables included in the regression analysis. However, there is an important variable identified in previous research that will be excluded from this study. Previous research has identified the importance of firm size to the difference in the propensity to patent (Fontana et al., 2013). The information regarding this variable is accessible for most of the innovating firms in SWINNO. However, the data needs to be organized and complementary sources are needed to register the size of some of the firms. This was deemed to be outside the scope of this thesis. Therefore, this variable has not been included in the analysis.

Regarding the novelty, one variable pertains to whether the innovation is new to the world market. Another novelty variable measures the novelty from the firm's perspective and categorizes them as either radical or major improvements in relation to the existing knowledge base of the firm (Sjöö et al., 2014, p. 27). The two complexity variables include artefactual complexity and developmental complexity. The artefactual complexity identifies if the innovation is a simple product (comprises few technological elements) or a complex system. The developmental complexity determines whether the innovation is of low complexity or high complexity regarding the knowledge involved in the development of the innovation (Sjöö et al., 2014, p. 25).

Accordingly, in a logistic regression model, the log of odds of the dependent variable (the probability to patent) is modeled as a linear combination of the independent variables. The regression model is given by:

$$log\frac{p_i}{1-p_i} = \sum_i \alpha_k C_k + \sum_i \beta_k N_k + \omega_{s(i)} + D_{t(i)} + \epsilon_i \qquad (3)$$

C_i is a set of variables measuring the complexity of the innovation; N_i measures the novelty of the innovation; $\omega_{s(i)}$ is the dummy variable for each industry sector from which it is possible to control the heterogeneity of industries; $D_{t(i)}$ represent a dummy variable for each of the amendments to the patent law (1975 and 1988) and takes the value of 1 if the commercialization year is greater or equal to the year of the amendment in question; ϵ_i *is* the error term. To capture any time-related effects, the thesis has included year dummies in the regression, but these are omitted in the equation here and the regression table. The results from the regression will be presented in section 6.

6 Empirical Analysis

This section presents the findings of the empirical analysis and discusses this in relation to previous research. The questions will be discussed using descriptive statistics, decomposition analysis and logistic regression.

6.1 Results

First, the average patent propensity over the whole period sums up to roughly 22%, as the number of innovations amount to 4460 and the number of patented innovations is 972. If one looks at figure 4, a noticeable inverted U-shape pattern is identified. This finding suggests that the propensity to apply for a patent in Japan between the years 1970-2015 could be divided into two trends.

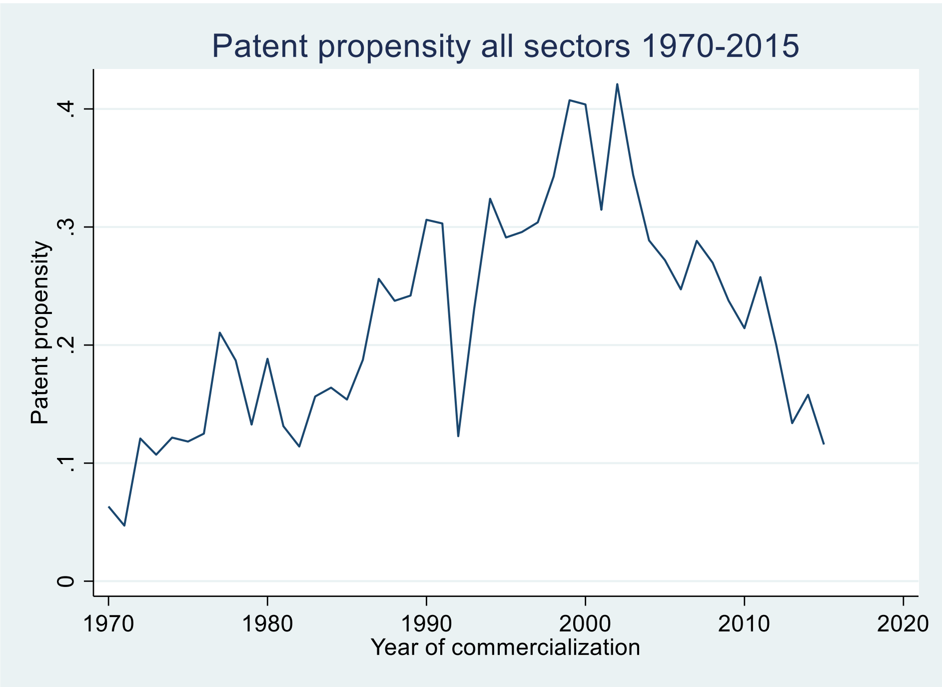

Figure 4 Propensity to patent in Japan across all sectors.

By commercialization year, 1970-2015

The propensity remained low at the beginning of the 1970s but started to steadily increase from 1972 to 1984. A significant increase continued until 2002 with the emergence of a pro-patent era in the late 1980s, albeit a trend deviation occurred in 1992. The share of patented innovations peaked in 2002 at 42 % and declined thereafter. The second trend began in 2002 with diminishing propensity levels. This drop coincides with the dot-com crash and a shift towards more qualitative patenting behavior among firms. The propensity has decreased on a yearly basis and the ratio narrowly reached 10 % in 2015.

If we examine the number of patented innovations, a few sectors remained dominant over the whole period, namely machinery and ICT (in this thesis the ICT sector consists of the sectors computers, electronics, electrical, telecommunication, and software). Machinery contributed to roughly 40-50 % of all patented innovations until the late 1980s (see figure 5). The number of patented ICT innovations grew in the 1970s and 1980s but experienced a remarkable surge in 1993 and onwards. The ICT sector evidently contributed to more than half of all patented innovations during the IT boom of the 1990s. In other words, ICT and machinery are the largest contributors to the increased overall patent numbers. In addition, the patent number does not decrease until 2012. This indicates the number of commercialized innovations increased during the early 2000s, but the propensity has decreased. The most significant drop happened in 2012 across all sectors. The only sector that seems to break this trend is the R&D sector which has generally increased the number of patented innovations since 2006, albeit the trend is volatile and starting from a low point.

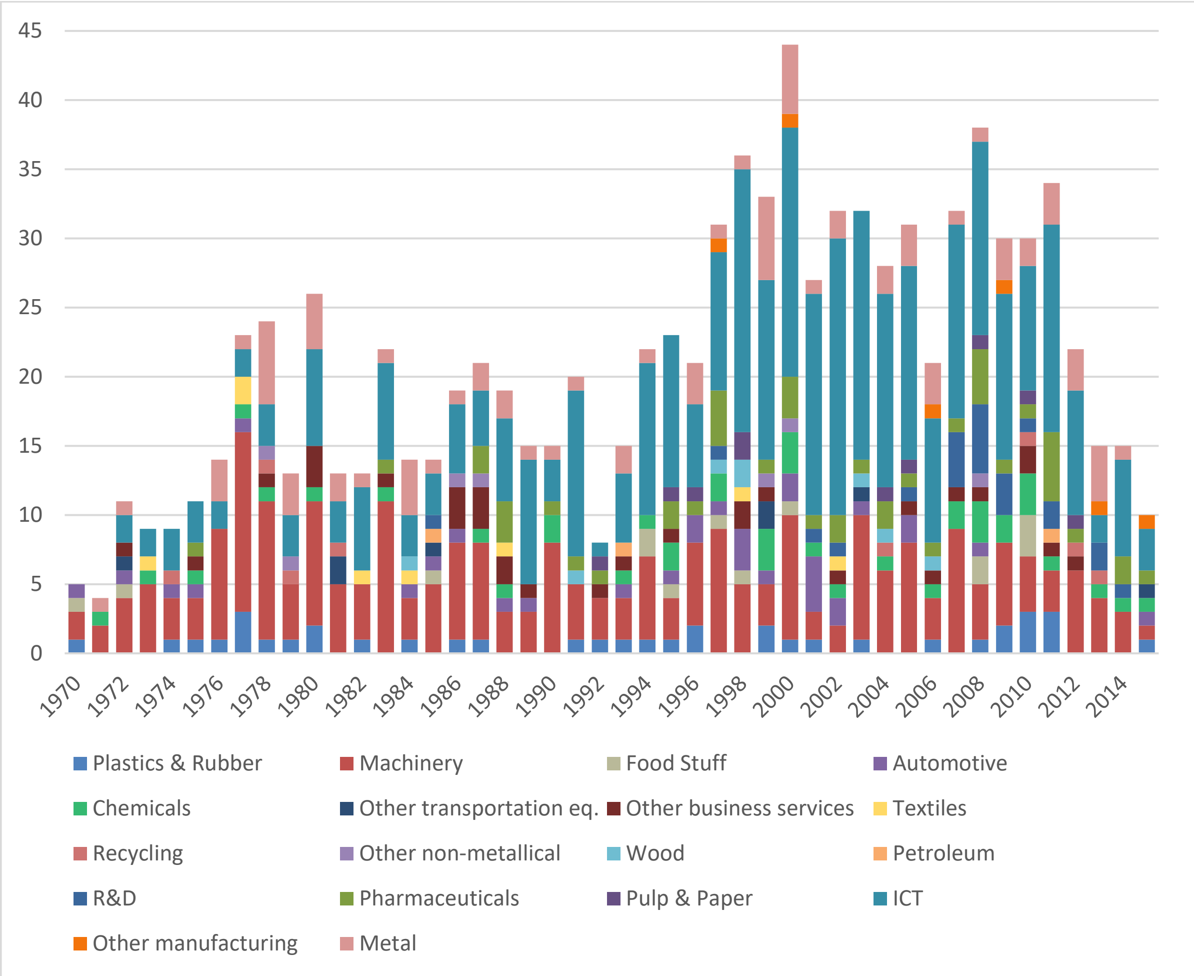

Figure 5 Number of patented innovations in Japan. By commercialization year, 1970-2015 (Sectors with less than 5 patented innovations are not presented)

At this point, it is imperative to investigate if the observed trends are valid for all sectors or if certain sectors inflate or deflate the overall propensity. The results finds that machinery and ICT are the biggest contributors to the number of patented innovations. To investigate whether the propensity trend is driven mainly by these two sectors,a decomposition analysis has been conducted. This is done by breaking down the sectors into three groups, namely “machinery”, “ICT”, and “other”. The results in table 1 indicate that the between effect and interaction effect are low and that the within effect is the predominant contributor to the average percentage point change in the patent propensity. Consequently, the results show that the trends in the patent propensity are driven across all sectors and not only inflated or deflated by certain sectors.

Table 1 Decomposition of average changes in the patent propensity

	1970-1980	1980-1990	1990-2000	2000-2015
Between effect	-0,006	-0,025	-0,035	0,013
Within effect	0,129	0,159	0,101	-0,302
Interaction	0,001	-0,016	0,026	-0,003
Changes aver. prop.	0,125	0,118	0,092	-0,292

Furthermore, if we look at the propensity level across all sectors, divided into three different time periods, it is evident also here that the trends occurred in almost all sectors between 1970 and 2015 (see table 2). However, the share of patented innovations varies across sectors. The years 1970-1985 shows the lowest observed propensity in almost all sectors. The highest being in textiles, a sector that previous literature have identified as a low propensity sector.

Table 2 Propensity to patent in Japan across all sectors

Sector	1970–1985	1986–2000	2001–2015
Automotive	12%	34%	28%
Basic metals	19%	57%	36%
Chemicals	18%	48%	31%
Computers	8%	15%	15%
Electrical apparatus	15%	37%	33%
Electronic eq.	13%	32%	31%
Fabricated metals	19%	24%	20%
Foodstuff	10%	44%	24%
Machinery	17%	29%	23%
Other business serv.	14%	29%	24%
Other manufacturing	7%	25%	20%
Other non-metallical	13%	38%	22%
Other transportation	6%	11%	10%
Petroleum	0%	50%	50%
Pharmaceuticals	18%	79%	69%
Plastics & rubber	16%	22%	18%
Publishing	0%	0%	25%
Pulp & paper	0%	38%	26%
R&D	0%	100%	60%
Software	0%	10%	11%
Telecommunication eq.	6%	28%	27%
Telecommunication serv.	0%	40%	14%
Textiles	38%	20%	9%
Wood	4%	19%	8%
Recycling	25%	0%	31%

The following period, 1986-2000, shows a serious increase across all sectors except for recycling and textiles. High-technology sectors such as pharmaceuticals and R&D have significantly high propensity during these years. The years 2001-2015 has previously been noted to be period of declining propensity. On a sectoral level, this seems to be true to almost all sectors. The exceptions are software, publishing, and recycling. The largest drop happened in telecommunication services, basic metals, and foodstuff. The findings signifies that the overarching patent trends occurred in the whole industry, although the propensity levels differ notably between sectors.

Since the thesis has identified the ICT sector and the machinery sector to have been a big contributor to the volumes of patented innovations, these two sectors will be analyzed. The machinery sector in figure 6 has a similar U-shaped progression. 1971 has the lowest recorded propensity, reaching only 7%. Although very volatile, the propensity to patent increased gradually from the 1970s and onwards. The propensity peaked at 50 % on two occasions: 1990 and 2007. Both peaks happened in conjunction with economic recessions, although dissimilar in how they developed in subsequent periods. The peak in 2007 was followed by a decrease in the propensity.

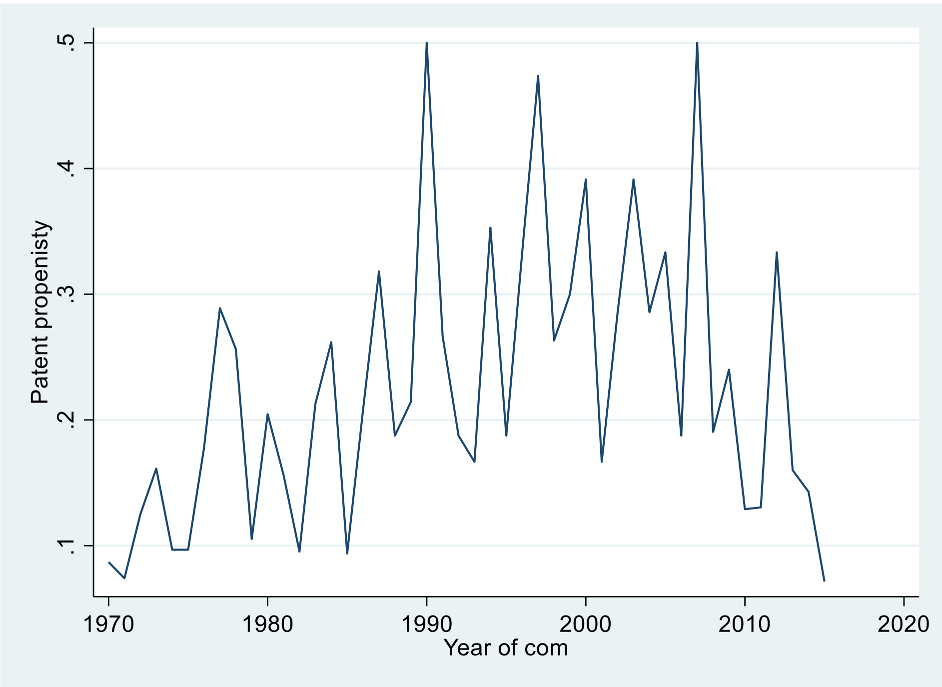

Figure 6 Propensity to patent in Japan in the Swedish machinery sector. By commercialization year, 1970-2015

The propensity to apply for a patent in the ICT sector has a similar development to machinery (see figure 7). A positive trend occurred in the ICT sector throughout the 1970s and the early 1980s. The substantial increase in the propensity happened in 1985 and except for a deviation in 1992 and 1998, the propensity increased until 2002. The most significant observation here is that it grew tremendously over a period of 30 years. In 1970, the propensity was virtually zero, and in 2002 it peaked at almost 50 %. The ICT sector remains a high propensity sector but is generally very volatile, and since 2012, the propensity has remained significantly low. The result from the ICT sector points to the fact that the decrease in patenting propensity happened earlier in the ICT sector, just after the dot-com crash, while the machinery sector started to decrease in propensity later in 2007.

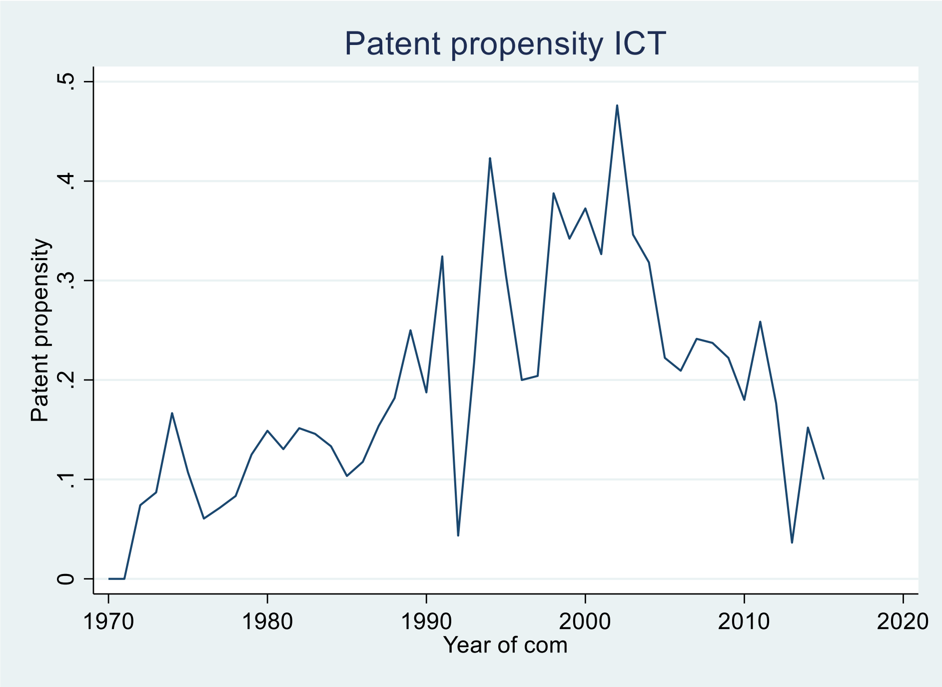

Figure 7 Propensity to patent in Japan in the Swedish ICT sector. By commercialization year, 1970-2015

Next, the result from the regression is presented in Table 3. The dependent variable is if the innovations are patented at the JPO, and the result is presented in log odds units. The probability to apply for a patent in Japan is highest and most significant in sectors such as pharmaceuticals, R&D, and basic metals. Other sectors that remain significant at a 0.05

percent level but are reported to have lower log odds are machinery, electrical, electronic, chemicals, and automotive.

Software is predicted to have a high negative impact on patenting. This observation is in line with the findings of previous literature (Chabchoub & Niosi, 2005). Furthermore, the regression shows ambiguous results regarding the amendments to the patent law. The amendment to the law in 1975 is only in one regression statistically significant at a 0.05 level and is observed to have a large positive impact on the propensity. The results from the amendment in 1988 are more robust, but the amendment is associated with a significant decrease in the likelihood of an innovation being patented in Japan. The implication of this will be discussed later.

The regressions also predict that the probability of patenting an innovation in Japan differs depending on the complexity and novelty. An innovation has a higher likelihood of being patented if it is categorized as having high developmental complexity and low artefactual complexity. The impact is particularly high for the developmental complexity. The result from the novelty is subdivided into two covariates: if the innovation is new to the world market and if it is new in relation to the existing knowledge of the firm. Both variables are recognized as statistically significant in the regression analysis and the probability is high, although the effect is larger if the innovations are new to the existing knowledge of the firm.

In addition, the results from the regression report that seven of the ten largest export sectors to Japan have a high statistical significance and with a higher likelihood of being patented in Japan. These sectors have already been discussed above and include machinery, electrical, electronics, automotive, pharmaceuticals, chemicals, and metal. While it has not been possible to include export figures in the logistic regression, Appendix A presents the correlation between export shares by sector and patent propensity for sub-periods. The results do not unanimously support the notion of an impact of export shares on patent propensity, but more research is needed.

Table 3 Logistic regression (log odds ratio). Dependent variable if innovations are patented at the JPO

	(1)	(2)	(3)
Dependent variable	JPO patent	JPO patent	JPO patent
law75	0.53	0.93**	0.61
	(0.45)	(0.44)	(0.45)
law88	-0.67	-0.97**	-0.71*
	(0.42)	(0.42)	(0.43)
New to the world market	0.50***		0.37***
	(0.09)		(0.09)
Radical	0.61***		0.76***
	(0.14)		(0.15)
Major	0.20		0.24
	(0.14)		(0.15)
Complex system	-0.25**		-0.32***
	(0.11)		(0.12)
Simple product	0.20**		-0.03
	(0.10)		(0.13)
High complexity	0.62***		0.52***
	(0.10)		(0.11)
Low complexity	-0.30**		-0.18
	(0.12)		(0.13)
Foodstuff		0.69*	0.55
		(0.39)	(0.40)
Textiles		0.69	0.62
		(0.46)	(0.48)
Wood		-0.70*	-0.66
		(0.42)	(0.43)
Pulp		0.42	0.46
		(0.36)	(0.37)
Chemicals		0.78***	0.56*
		(0.27)	(0.29)
Pharmaceuticals		2.25***	1.76***
		(0.32)	(0.33)
Plastics		0.29	0.29
		(0.26)	(0.27)
Basicmetals		1.18***	1.31***
		(0.29)	(0.30)
Fabricated		0.43*	0.49*
		(0.25)	(0.25)
Machinery		0.52***	0.56***
		(0.20)	(0.20)
Computers		-0.32	-0.35
		(0.28)	(0.29)
Electrical		0.80***	0.68***
		(0.25)	(0.26)
Telecommunication		0.30	0.16
		(0.23)	(0.23)
Electronic		0.58***	0.42**
		(0.20)	(0.21)
Automotive		0.44	0.56**
		(0.28)	(0.28)
Recycling		0.96*	0.75
		(0.49)	(0.51)
Software		-0.79***	-0.96***
		(0.26)	(0.27)
r&d		2.16***	1.75***
		(0.40)	(0.40)
Other business		0.39	0.20
		(0.29)	(0.29)
Constant	-2.32***	-2.50***	-2.79***
	(0.38)	(0.40)	(0.43)
N	4460	4460	4460
R-square	0.0814	0.858	0.1153

Standard errors in parentheses

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

6.2 Discussion

6.2.1 Patent propensity in Japan

It is helpful at this stage to repeat the first research question: *How many Swedish innovations were applied for a patent in Japan during the period 1970-2015?* The data sources contain 4460 innovations, and out of these 972 were applied for an application at the Japanese Patent Office. The average propensity over the whole period is estimated to be 22%. It is useful here to compare these findings with previous literature on the subject. Previous assessments of patent propensity vary depending on the measurement techniques and the data sources used. As it turns out, the findings from this thesis are comparable to the propensity found in the study of Brouwer and Kleinknecht (1999), that showed a 25 % patent propensity. An average propensity of 22 % implicates that with the method and data sources applied in this thesis, there is a significant number of non-patented innovations captured with the LBIO-method. Although not controversial and in line with previous observations, it is fair to conclude that far from all innovations are patented, and not all inventions are commercialized.

6.2.2 Trends in the patent propensity

The findings of this thesis suggest that the propensity to patent varies over time. This leads us to the second research question: *What trends are there in the propensity to patent in Japan among Swedish firms?* The findings have identified two trends in patent propensity. The patenting practices among Swedish firms increased during the first trend in the early 1970s. The expansion intensified in 1985 and culminated in 2001. The second trend could be defined as a break from this course as the propensity decreased on an annual basis between 2002-2015. The result from the decomposition analysis also shows that both trends happened across all sectors.

The trends described here tend to support the first and second hypotheses. The extensive patenting period coincides with the emergence of a pro-patent era, as discussed by Granstrand (2016). However, the thesis finds that the extensive patenting period precedes events of the pro-patent era, as it initially began to rise already in the late 1970s. The enablement of a pro-patent era could partly be ascribed to the harmonization of patent laws. However, the results from the graphs and the regression analysis show that the harmonization of patent laws in 1975 influenced the propensity but the amendment in 1988 did not. This might indicate that the harmonization has an ambiguous impact on patenting activities among Swedish innovating firms. For example, the propensity decreased after 2002 regardless of harmonization of the Japanese patent law. The results point to the fact that the propensity to patent a Swedish innovation at the JPO may be attributable to other factors than law harmonization. Nevertheless, the tremendous increase in patent propensity from the late 1980s until 2002 is in line with the emergence of a pro-patent era. Granstrand and Holgersson (2012) have also shown that a deviation from this trend occurred in 1992, which coincides with the financial crisis in Sweden. This deviation has also been identified in this thesis.

The second observed trend is a decline in propensity that began in 2002. This shift is valid for all sectors, although the thesis founds that the ICT sector was relatively more affected by the trend break. It had an immediate negative effect on the patent propensity. This is not surprising since the trend break occurred in conjunction with the dot-com crash. This second trend partly corroborates with previous findings by Granstrand and Holgersson (2012). Granstrand & Holgersson argue that changes in the patent propensity among Swedish firms are related to changes in R&D and patenting resources and a shift towards selective and qualitative patenting strategies. Despite this, the shift affected the propensity more than expected. The source data used in this thesis consist of significant innovations which implies that they are of high economic and technological value for the innovating firm. The indication is that the incentive to patent at the JPO is high. The shift toward a selective and qualitative patent approach suggests that the number of patents application per innovation will decrease. However, it also suggest that with the increased patent awareness, the propensity will simultaneously stay relatively high. However, the findings of this thesis show that the aggregated propensity has decreased so profoundly between 2002-2015 that this trend should probably not be defined as a quality-oriented pro-patent era regarding Swedish innovating firms. This implies that the shift in patent strategies has reduced the incentive for Swedish innovating firms to patent their innovation at the JPO.

One explanation for this could be that innovating firms perceived the Japanese market to be a less attractive market after the trend break in 2002. The Swedish export to Japan declined between 2002-2015 (see figure 2) compared to the export surge in the 1990s. However, the patent propensity has decreased significantly more than these observations, so a more likely explanation may be that patents have become a less valuable protection mechanism for Swedish innovating firms in relation to Japan after 2002. This implies that patents are of relatively low priority when an innovating firm decides to enter the Japanese market or collaborate with Japanese firms. Other IP mechanisms, such as lead time or trade secrecy, are likely to be more important for securing returns to innovation in the Japanese market after 2002. However, these explanations are at this stage highly tentative, and future research is needed to discuss this matter. Questions arise as to how this shift in patent strategies has affected the firm's export performance to Japan and what alternative IP mechanisms the innovating firms are applying instead of patents. Finally, further research needs to dwell more on why a foreign application at the JPO has become a less valuable source of protection and if this observation is applicable to other patent offices.

6.2.3 Types of innovations that are patented in Japan

The third research question is the following: *What types of innovation tend to be patented in Japan?*

The machinery and ICT sectors remained the main contributors to the number of patented innovations over the whole observed period. The machinery sector attributes to approximately 25 % of all patented innovations. The ICT sector experienced a surge in the late 1970s and comprises roughly 36% of all patented innovations between 1970-2015. As established in section 2, these sectors have historically been exposed to Japanese competition and are large export sectors to Japan.

The thesis finds that the propensity to patent an innovation at the JPO varies across industry sectors. This observation underpins previous research on this matter (Brouwer & Kleinknecht, 1999; Fontana et al., 2013). In addition, the regression analysis reports that innovations with high artefactual complexity are less prone to be patented. This underscores previous suggestions by Arundel and Kabla (1998) that complex innovations have in general lower patent propensity and tend to favor other appropriability mechanisms, i.e., lead time and secrecy. On the contrary, the patent propensity is on average higher when an innovation has high developmental complexity. High-technological sectors are more prone to patent their innovations. Thus, this tends to support the third hypothesis and underlines previous research (Chabchoub & Niosi, 2005; Arundel & Kabla, 1998). The result from the regression analysis also reveals that software has a negative impact on patent activities which is in line with previous findings by Chabchoub & Niosi (2005). Although just a handful of software innovations are patented, the propensity has increased since 2001 and this trend diverges from other sectors during this period. In addition, the regressions present some surprising results. Basic metals are identified as a sector with significantly high patent propensity, and this stand in contrast to previous literature (Fontana et al., 2013). Furthermore, the propensity to apply for a patent is on average higher among innovations identified as new to the market and new to the firm. The conclusion from this is that a patent is deemed to be a crucial protection mechanism for innovations that exhibits unique and novel technologies.

As noted from the regression analysis, the patent propensity is high in sectors identified with high export sector shares to Japan. These sectors include pharmaceuticals, electronics, electricals, chemicals, automotive, machinery, and basic metals. However, the correlation between the sectoral propensity and the export share by sector does not show any statistical significance. The only correlation considered herein is the electronic and electrical sectors during the 1990s. Having this said, this thesis does not intend to investigate the relationship between patenting activities and patent exports. As it turns out, the overall propensity has since 2001 declined profoundly while the exports have not diminished at the same rate. Nevertheless, the findings lend support to the fifth hypothesis. The propensity to apply for a patent in Japan is significant in industries with high economic involvement and relatively high shares of the total export to Japan.

The findings of the types of innovation patented in Japan highlight an important aspect of the Swedish patenting behavior at the JPO: Swedish innovating firms' patenting activities increased significantly from the late 1970s when Japan established itself as a global leading actor in many high-technology industries. This suggests that Swedish innovating firms increased their patent activities at the JPO to stay competitive in high-technology sectors. The importance of patents was exacerbated by the IVA/PRV-study from 1992 when Japan was pointed out as the "best practice" regarding patent strategy and management. However, these patterns have changed significantly from this period to a more selective approach beginning in 2002.

7 Conclusion

7.1 Research Aims & Conclusion

The purpose of this thesis is to provide knowledge about the historical development of Swedish innovating firms' patent activities at the Japanese Patent Office. It also aims to contribute to the debate on the role of patents for Swedish innovating firms if/when they are entering the Japanese market or initiating business relation with Japanese clients. This is done by analyzing and identifying patenting patterns and the characteristics of the patented innovations. By using new and unique records from the database SWINNO stretching from 1970 to 2015, the thesis has contributed with novel findings on this matter.

The thesis shows that the overall propensity to apply for a patent at the JPO between 1970-2015 amount to 22%. However, the patenting patterns varies over time and the thesis has identified two different trends. The first trend is defined as an expansive period that began in the late 1970s and ended in 2001. The thesis argues that this trend is part of the emergence of a pro-patent era. The second pattern is recognized as a period of decline with a profound decrease in the propensity from 2001 until 2015. This pattern has been identified as the end of the pro-patent era among Swedish innovating firms in regard to their patent activities at the JPO. This suggest that a shift toward a selective and qualitative patenting approach lowered the incentive to patent at the JPO. A possible implication is that patent has become a relatively low priority appropriation mechanism for Swedish innovating firms when/if they enter the Japanese market. Moreover, the impact of amendments to the Japanese patent law in the thesis shows ambiguous results. The amendment in 1975 shows a positive impact, while the amendment in 1988 shows a negative impact. This suggests that the patent laws have had a limited effect on the patent propensity among Swedish innovating firms.

The thesis discovered that the types of innovation patented in Japan are in line with previous findings on this matter. The probability of patenting is high in high-technology sectors, i.e., R&D and pharmaceuticals and low in wood and software. The propensity is also high in sectors with high exports to Japan, such as machinery, automotive and electrical. Finally, the thesis reveals that the importance of patent as a protection mechanism is high if the innovation exhibits unique and novel technologies and low if the innovation comprises many technological elements.

7.2 Limitations

The covariates applied in this thesis comprise several variables identified as key factors that can affect the patent propensity. However, the firm-size has been deliberately omitted. This variable will doubtless have an impact on the patent propensity. However, assembling this data was outside the scope of this thesis. In addition, the identification of the ten largest export sectors was based on available export data from Trading Economics between 1992-2018. Thus, the years 1970-1991 have not been included in the analysis. Sectors with high export shares to Japan pre-1992 are therefore not represented.

7.3 Future research

The thesis finds that the incentives to patent at the Japanese Patent Office have fluctuated over time. The period between 2002-2015 shows a profound drop in patent propensity. As previously discussed, future research needs to be conducted in this area to understand the factors behind this pattern. Foremost, we need to address the possible reasons why a JPO-patent has become a less valuable protection mechanism among Swedish innovating firms. This is pivotal since the prospect of obtaining a patent in Japan has increased over time. Firm surveys can inform us about the importance of patents when firms enter the Japanese market or initiate business with Japanese partners. These surveys ought to investigate what other IP mechanisms are used by innovating firms and how this has affected their possibilities to do business in Japan. In addition, more research is unquestionably needed to understand other factors behind patenting behavior among Swedish innovating firms. Research also needs to incorporate the firm size as a covariate to understand the trends observed in this thesis. Future research should also be conducted on potentially negative aspects associated with patents.

Patent flooding and other patent strategies challenge the effectiveness of patents and can become an obstacle to future innovation and international business relations.

Reference

Abe, T. (2017). The History & Significance of Japan's Trade & Industrial Policy-a Case Study of Trade Friction at the End of the 20th Century, *Economic History,* no. 12**,** pp. 50-54, Available online: https://www.jef.or.jp/jspotlight/backnumber/detail/216/ [Accessed 22 March 2022]

Altomonte, C., Aquilante, T., Békés, G. & Ottaviano, G. I. P. (2014). Internationalization and Innovation of Firms: Evidence and Policy, *Economic Policy,* vol. 28, no. 76**,** pp. 663-700, Available online: https://doi.org/10.1111/1468-0327.12020 [Accessed 16 March 2022]

Arundel, A. & Kabla, I. (1998). What Percentage of Innovations Are Patented? Empirical Estimates for European Firms, *Research policy,* vol. 27, no. 2**,** pp. 127-141, Available online: https://doi.org/10.1016/S0048-7333(98)00033-X [Accessed 19 March 2022]

Bain, D. & Kleinknecht, A. (2016). New Concepts in Innovation Output Measurement. Springer

Brouwer, E. & Kleinknecht, A. (1999). Innovative Output, and a Firm's Propensity to Patent.: An Exploration of Cis Micro Data, *Research policy,* vol. 28, no. 6**,** pp. 615-624, Available online: https://doi.org/10.1016/S0048-7333(99)00003-7 [Accessed 22 March 2022]

Business Sweden (2021). Business Climate Survey for Swedish Companies in Japan 2021, Available online: https://www.business-sweden.com/sv/insikter/rapporter/japan-2021-business-climate-survey/ [Accessed 15 January 2022]

Cassiman, B. & Golovko, E. (2011). Innovation and Internationalization through Exports, *Journal of International Business Studies,* vol. 42, no. 1**,** pp. 56-75, Available online: https://doi.org/10.1057/jibs.2010.36 [Accessed 5 March 2022]

Castellani, D. & Zanfei, A. (2007). Internationalisation, Innovation and Productivity: How Do Firms Differ in Italy?, *The World Economy,* vol. 30, no. 1**,** pp. 156-176, Available online: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-9701.2007.00875.x [Accessed 9 February 2022]

Caviggioli, F. (2011). Foreign Applications at the Japan Patent Office–an Empirical Analysis of Selected Growth Factors, *World Patent Information,* vol. 33, no. 2**,** pp. 157-167, Available online: https://doi.org/10.1016/j.wpi.2010.12.002 [Accessed 26 March 2022]

Chabchoub, N. & Niosi, J. (2005). Explaining the Propensity to Patent Computer Software, *Technovation,* vol. 25, no. 9**,** pp. 971-978, Available online: https://doi.org/10.1016/j.technovation.2004.02.015 [Accessed 20 March 2022]

Cohen, W. M., Goto, A., Nagata, A., Nelson, R. R. & Walsh, J. P. (2002). R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States, *Research Policy,* vol. 31, no. 8, pp. 1349-1367, Available online: https://www.sciencedirect.com/science/article/pii/S0048733302000689 [Accessed 20 March 2022]

Cohen, W. M., Nelson, R. & Walsh, J. P. (2000). Protecting Their Intellectual Assets: Appropriability Conditions and Why Us Manufacturing Firms Patent (or Not), NBER working paper, no. 7552, Available online: https://doi.org/10.3386/w7552 [Accessed 2 March 2022]

Ehrnberg, E. & Jacobsson, S. (1993). Technological Discontinuity and Competitive Strategy—Revival through Fms for the European Machine Tool Industry?, *Technological Forecasting and Social Change,* vol. 44, no. 1, pp. 27-48, Available online: https://doi.org/10.1016/0040-1625(93)90004-Q [Accessed 13 March 2022]

Fagerberg, J., Mowery, D. C. & Nelson, R. R. (2005). The Oxford Handbook of Innovation: Oxford University Press.

Fontana, R., Nuvolari, A., Shimizu, H. & Vezzulli, A. (2013). Reassessing Patent Propensity: Evidence from a Dataset of R&D Awards, 1977–2004, *Research Policy,* vol. 42, no. 10, pp. 1780-1792, Available online: https://doi.org/10.1016/j.respol.2012.05.014 [Accessed 24 March 2022]

Frietsch, R., Neuhäusler, P., Jung, T. & Van Looy, B. (2014). Patent Indicators for Macroeconomic Growth—the Value of Patents Estimated by Export Volume, *Technovation,* vol. 34, no. 9, pp. 546-558, Available online: https://doi.org/10.1016/j.technovation.2014.05.007 [Accessed 2 April 2022]

Fukao, K., Ikeuchi, K., Kim, Y. & Kwon, H. U. (2016). Why Was Japan Left Behind in the Ict Revolution?, *Telecommunications Policy,* vol. 40, no. 5, pp. 432-449, Available online: https://doi.org/10.1016/j.telpol.2016.01.008 [Accessed 20 February 2022]

Granstrand, O. & Holgersson, M. (2012). The Anatomy of Rise and Fall of Patenting and Propensity to Patent: The Case of Sweden, *International Journal of Intellectual Property Management,* vol. 5, no. 2, pp. 169-198, Available online: https://www.ip-research.org/articles/the-anatomy-of-rise-and-fall-of-patenting-and-propensity-to-patent-the-case-of-sweden/ [Accessed 16 March 2022]

Hayashi, F. & Prescott, E. C. (2002). The 1990s in Japan: A Lost Decade, *Review of Economic Dynamics,* vol. 5, no. 1, pp. 206-235, Available online: https://www.sciencedirect.com/science/article/pii/S1094202501901498 [Accessed 20 March 2022]

Ikekuchi, K. (2017). Kigyō No Inobēshon Autoputto No Tamen-Teki Sokutei [Multi-Dimensional Measurement of Innovation Outputs by Firms], *NISTEP DISCUSSION*

PAPER, no.149, National Institute of Science and Technology Policy, Tokyo, Available online: https://nistep.repo.nii.ac.jp/?action=pages_view_main&active_action=repository_view_main_item_detail&item_id=4224&item_no=1&page_id=13&block_id=21 [Accessed 20 January 2022]

Johansson, M., Nyqvist, J. & Taalbi, J. (2022). Linking Innovations and Patents - a Machine Learning Assisted Method, Available online: https://ssrn.com/abstract=4127194 [Accessed 3 June 2022]

Kleinknecht, A., Van Montfort, K. & Brouwer, E. (2002). The Non-Trivial Choice between Innovation Indicators, *Economics of Innovation and new technology,* vol. 11, no. 2, pp. 109-121, Available online: https://www.researchgate.net/publication/24078379_The_Non-Trivial_Choice_Between_Innovation_Indicators [Accessed 12 March 2022]

Kotabe, M. (1992). A Comparative Study of Us and Japanese Patent Systems, *Journal of International Business Studies,* vol. 23, no. 1, pp. 147-168, Available online: https://doi.org/10.1057/palgrave.jibs.8490263 [Accessed 20 February 2022]

Kozu, T., Nakayama, K., Mineshima, A. & Saita, Y. (2002). Changes in Japan's Export and Import Structures, *Bank of Japan Monthly Bulletin,* Available online: https://www.boj.or.jp/en/research/brp/ron_2002/data/ron0205a.pdf [Accessed 10 March 2022]

Kviselius, N. Z. (2008). Trust-Building and Communication in Sme Internationalization : A Study of Swedish-Japanese Business Relations, Stockholm: Economic Research Institute, Stockholm School of Economics, Available online: http://www2.hhs.se/efi/summary/741.htm [Accessed 15 January 2022]

Myers Jr, J. P. & Yamakoshi, K. (2020). The Japanese Fifth Generation Computing Project: A Brief Overview, *Journal of Computing Sciences in Colleges,* vol. 36, no. 2, pp. 53-60, Available online: https://dl.acm.org/doi/10.5555/3447065.3447072 [Accessed 10 February 2022]

Nagaoka, S. (2009). Reform of Patent System in Japan and Challenges, *21st Century Innovation Systems for Japan and the United States: Lessons from a Decade of Change: Report of a Symposium,* pp. 153-168, Available online: https://doi.org/10.17226/12194. [Accessed 20 February 2022]

Nagaoka, S., Motohashi, K. & Goto, A. (2010). Patent Statistics as an Innovation Indicator, *Handbook of the Economics of Innovation,* vol. 2, pp. 1083-1127, Available online: https://doi.org/10.1016/S0169-7218(10)02009-5 [Accessed 16 February 2022]

Neuhäusler, P. (2012). The Use of Patents and Informal Appropriation Mechanisms—Differences between Sectors and among Companies, *Technovation,* vol. 32, no. 12, pp. 681-693, Available online:

https://www.sciencedirect.com/science/article/pii/S0166497212000806 [Accessed 20 March 2022]

Näringsdepartementet (2006). Patent Och Innovationer För Tillväxt Och Välfärd, *Fritzes förlag,* SOU:80**,** Available online: https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2006/12/sou-200680/ [Accessed 3 January 2022]

OECD & Eurostat. (2018). Oslo Manual 2018, Available online: https://doi.org/10.1787/9789264304604-en [Accessed 21 April 2022]

Sakakibara, M. & Branstetter, L. G. (1999). Do Stronger Patents Induce More Innovation? Evidence from the 1988 Japanese Patent Law Reforms, Working paper, no. 7066, Available online: http://dx.doi.org/10.3386/w7066 [Accessed 2 March 2022]

Scherer, F. M. (1983). The Propensity to Patent, *International Journal of Industrial Organization,* vol. 1, no. 1**,** pp. 107-128, Available online: https://doi.org/10.1016/0167-7187(83)90026-7 [Accessed 2 March 2022]

Schumpeter, J. A. (1939). Business Cycles: Mcgraw-hill New York, Available online: https://www.mises.at/static/literatur/Buch/schumpeter-business-cycles-a-theoretical-historical-and-statistical-analysis-of-the-capitalist-process.pdf [Accessed 18 March 2022]

Sjöö, K., Taalbi, J., Kander, A. & Ljungberg, J. (2014). Swinno: A Database of Swedish Innovations, 1970-2007, *Lund Papers in Economic History,* General Issues, no. 133, Department of Economic History, Lund University, Available online: https://lucris.lub.lu.se/ws/portalfiles/portal/5522430/7868934 [Accessed 18 February 2022]

Taalbi, J. (2014). Innovation as Creative Response. Determinants of Innovation in the Swedish Manufacturing Industry, 1970-2007: Lunds University (Media-tryck), Available online: https://portal.research.lu.se/sv/publications/innovation-as-creative-response-determinants-of-innovation-in-the [Accessed 12 January 2022]

Taalbi, J. (2018). Origins and Pathways of Innovation in the Third Industrial Revolution, *Industrial and Corporate Change,* vol. 28, no. 5**,** pp. 1125-1148, Available online: https://doi.org/10.1093/icc/dty053 [Accessed 16 January 2022]

Taalbi, J. (2022). Innovation with and without Patents. *Mimeo, Dept. of Economic History.*

The Japanese Patent Office (2022). Available online: https://www.jpo.go.jp/e/resources/statistics/index.html [Accessed 17 April 2022]

Trading Economics (2022). Available online: https://tradingeconomics.com/sweden/exports/japan [Accessed 17 January 2022]

Willquist, S. (2018). Sweden and Japan Celebrate 150-Year Anniversary as Jpo Relaxes Patent Approach, Available online: https://www.iam-media.com/sweden-and-japan-celebrate-150-year-anniversary-jpo-relaxes-patent-approach [Accessed 20 February 2022]

Wineburg, A. (1988). Japanese Patent System: A Non-Tariff Barrier to Foreign Businesses, *J. World Trade,* vol. 22, no. 11, Available online: https://heinonline.org/HOL/LandingPage?handle=hein.kluwer/jwt0022&div=6&id=&page= [Accessed 22 March 2022]

Yamashita, N. (2021). Economic Crisis and Innovation Capacity of Japan: Evidence from Cross-Country Patent Citations, *Technovation,* vol. 101, no. 102208, Available online: https://doi.org/10.1016/j.technovation.2020.102208 [Accessed 19 April 2022]

Appendix A

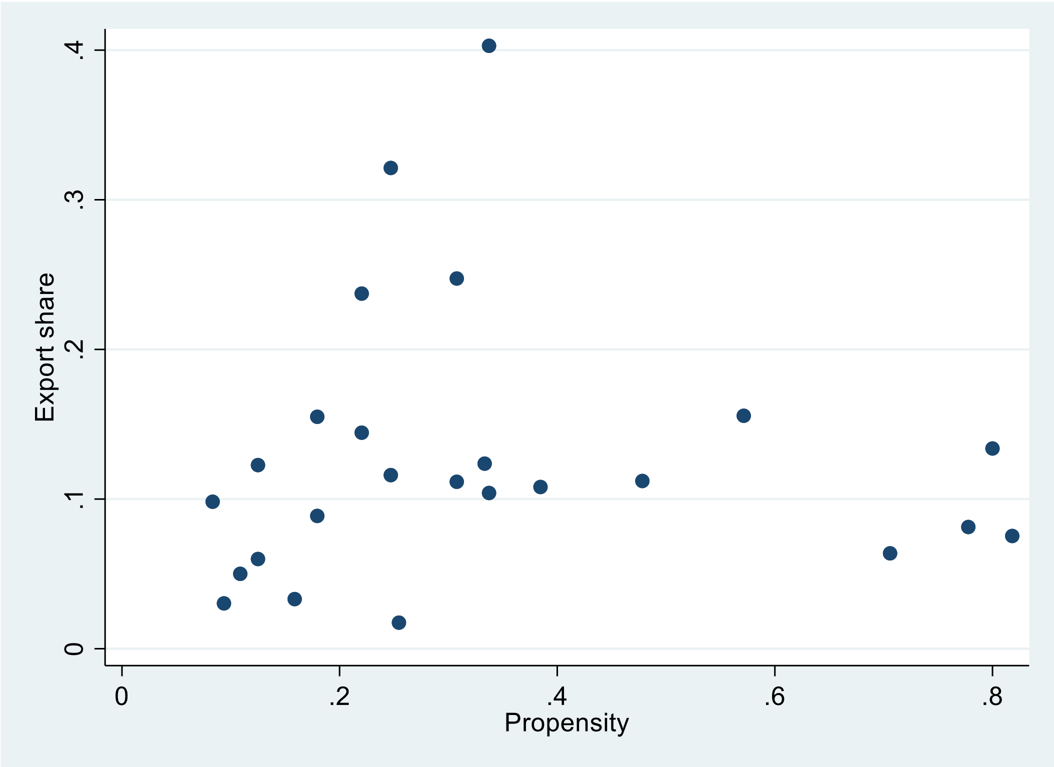

Figure 8 Scatter plot patent propensity in Japan on export share by sector for subperiods of five years between 1992-2015