Patents as a source of finance to mitigate financing constraints

Main Findings

Academic research grant 2019

Felix Bracht[a] and Dirk Czarnitzki[a, b, c]

[a] *KU Leuven, Dept. of Management, Strategy and Innovation, Leuven, Belgium*
[b] *Center for R&D Monitoring (ECOOM) at KU Leuven, Belgium*
[c] *Centre for European Economic Research (ZEW), Mannheim, Germany*

July 8, 2022

Contents

Executive Summary

The purpose of this project was to collect data on patents that were used as collateral in loan negotiations in four countries (Sweden, the Netherlands, Belgium and Luxembourg) where it is mandatory to report to the local patent authority if intellectual property rights have been pledged. In addition, we proposed to conduct economic analyses of pledged patents in order to shed some light on

I. how frequently are patents used as collateral,

II. which patents are used as collateral,

III. which type of firms pledge patents,

IV. whether we can use pledged patents to estimate their value through firms' debt levels,

V. whether patent–pledging is effective in mitigating financing constraints of corresponding firms significantly.

First, the data on the four countries has been collected. However, the number of pledged patents in Luxembourg and Belgium are small and therefore not used further for statistical analyses in this project. For Sweden and the Netherlands, we constructed panel data on patenting firms using the Orbis Global database as well as Orbis IP and the Patstat database. We thus obtain firm-level patent data in which we can observe detailed financial information for patenting firms including pledgors.

A descriptive analysis of pledged vs. non-pledged patents shows that the pledged patents are on average more frequently cited by subsequent patented inventions and have more patent-family members. A descriptive analysis at the firm-level shows that the majority of patent pledging firms are small with less than 50 employess and younger firms, i.e. less than 10 years old. A look at the pledging firms' patent portfolios shows that the pledgors typically do not collateralize all of their patents but a selection.

In a first econometric analysis, we explore which patent characteristics are associated with pledging. In accordance to the financial literature three factors "physical attributes of the asset", "firm-specificity of the asset" and "financial strength of alternative users" determine the liquidation value, which in turn, is the main driver for loan collateral. Hence, we consider patent indicators on patent quality, the firm-specificity of the underlying technology and the financial strength of a patent's alternative users. We find evidence that patents' quality matter for collateralization, e.g. forward citations and family members. However, we do not find support that patents protecting technologies specific to the owning firm are less suited for collateral. Neither do we find evidence that

the financial strength of alternative users matters. Both factors are important determinants for the salability of an assets. Hence, pledgees (which are mainly banks) do not seem to take the salability of patents into account.

In a second econometric analysis, we explore the effect that the event of a patent pledge has on the pledgor's access to external capital as measured by debt at the firm level. We show for samples of Dutch and Swedish patenting firms that the patent pledging event causes an increase in the level of debt by about 20% (34%) for Swedish (Dutch) firms. In absolute numbers, patent pledgors raised, on average, € 1.4 million additional capital in the Netherlands and € 1.2 million in Sweden.

In summary, we conclude that patent pledging can significantly mitigate financing constraints by easing the access to external finance. We also observe that patent pledging is still a relatively rare event and it thus seems that the markets for patent collateral are yet to be further developed even in highly industrialized European countries.

1 Database construction

In order to investigate the use of patent pledging as a source of finance, we require detailed firm–level information on balance sheet and income statement data combined with detailed information on patents owned by respective firms. The registration of pledged patents is determined by the national patent law and is not mandatory in most countries. However, the Swedish, Dutch, Belgian and Luxembourgian patent offices are one of the few national patent offices where the registration of collateralized patents is mandatory. (Ministry of Justice Stockholm 1967*a*, *Patent Act 1995* n.d.) Consequently, we have collected information on pledged patents from these countries.

1.1 Raw data collection

The data can be obtained from the websites of the national patent offices. The BeNeLux countries share the same IT platform, but Sweden has its own system. A bulk–download of the pledged patent data is not possible and therefore web–scraping tools have been applied.

All databases have in common they contain information about the patent number for all national and EP-patents valid in the respective country and the pledgee. In addition, the BeNeLux system contains a variable called "deed date". This is the date when the patent has been reported as pledged to the patent office. In Sweden the database contains the actual date of the corresponding loan contract, which is different from the registration date in the patent database. After personal communication with the Dutch patent office, we obtained in addition to the data published on the website also information on the actual dates of the corresponding loan contracts, and it shows that for the vast majority of the cases, the "deed date" is very close to the date of the loan contract.

A further level of complexity is added by the fact that the pledgor is not necessarily equal to the original patent owner that is registered in PATSTAT. From the Dutch and Swedish data, it can be inferred that the patent has switched owners between the filing date of the application and the pledging date when the identities of patentee (as retrieved through the patent application number) and the pledgor are different. Thus possible, existing database links between patent applications and firms that were established based on firm–level data and patent filing data have to be ex–post corrected for ownership changes of (pledged) patents.

1.1.1 Country data: Sweden

The Swedish data covers all pledged patents between 1981 to 2015. The raw data spread sheet obtained from the web-scraping exercise contains 1,402 rows. This number is, however, somewhat misleading as a patent might (i) be pledged multiple times, (ii) have

multiple owners and pledgors, (iii) a loan contract might involve multiple pledgees. The 1,402 rows in the raw data spread sheet refer to 1,287 Swedish national patents or EP-patents valid in Sweden that have been pledged by 644 entities in that time period. Figure 1a shows the yearly number of patent pledging entities for Sweden. Using the number of entities rather than the number of patents seems a better representation of the annual patent pledging activity, because many entities pledge entire patent portfolios rather than single patents. The number of patent pledging firms in Sweden shows a slight increase until 2007 interrupted by drops in 2000 and 2008. This can be explained by the dot–com bubble and the global financial crisis 2008/9. Ivashina & Scharfstein (2010) claim that during the financial crises new loans to borrowers fell dramatically, making the demand for collateral needless.

1.1.2 Country data: The Netherlands

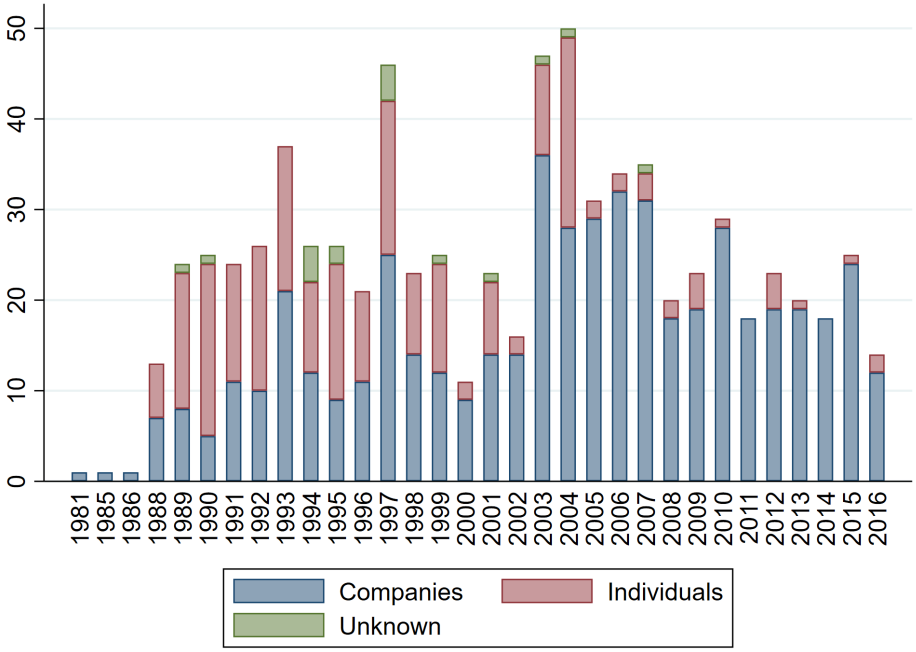
For the Netherlands, the raw data spread sheet contains 5,920 rows. These refer to 2,590 national or EP-patents valid in the Netherlands that have been pledged by 741 entities between 1984 and 2019. In contrast to Sweden, the annual patent pledging activity in the Netherlands shows an increasing trend until 2012 (Figure 1b). This might indicate that patent pledging is less driven by business-cycles in the Netherlands. The low number of pledged patents in recent years can be explained by truncation.

1.1.3 Country data: Belgium and Luxembourg

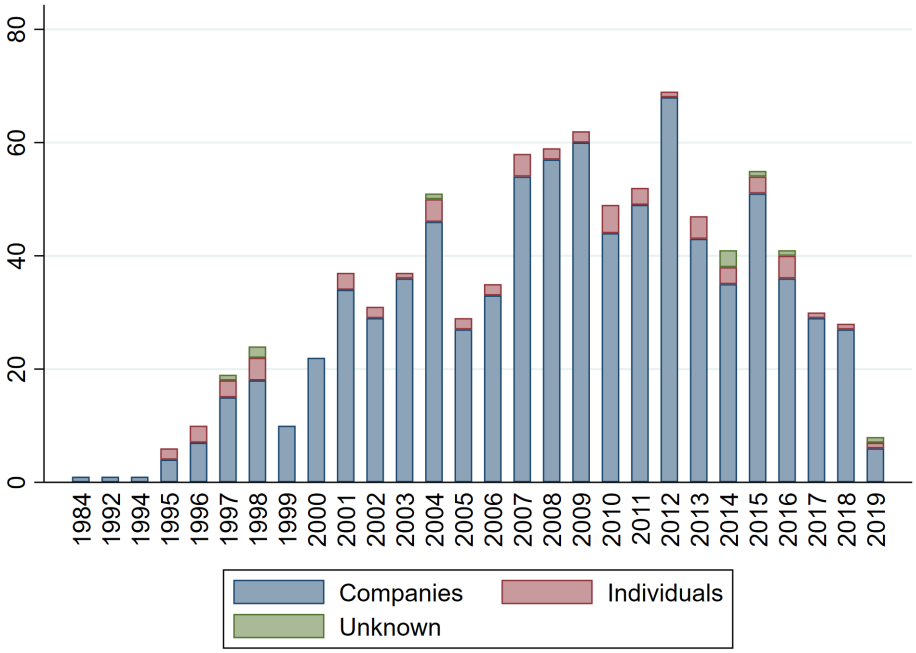
The Belgian Office for Intellectual Property could only provide information about pledged patents beginning in 2014 due to a change in the IT-system. The patent pledging activity in Belgium is very low with only 42 entities pledging 66 patents between 2014 and 2020. For Luxembourg, the number is also low with 57 patents between 2005 and 2019. Because of these small samples, we do not consider Belgian and Luxembourgian data further within this project.

1.2 Linking databases

In a next step, all Swedish and Dutch firms pledging patents have been matched with detailed firm level data from the national statistical offices. Patent pledging firms have been matched manually based on firm names and addresses. In contrast to the Netherlands, the Swedish patent data does not record exact information about the pledgor of the patent. Instead, the Swedish patent office, PRV, provides information about change of ownership for all patents to derive the patent owner at the time the pledge was granted. The data covers basic information about the firms, yearly balance sheet and income statement data. Since the empirical analysis is focusing on domestic firms, pledged patents



(a) Sweden



(b) Netherlands

Figure 1: Annual number of patent pledging events per entity.

owned by individuals or foreign firms are not considered. Additionally, the Swedish and Dutch statistical offices have matched firm–level data with all patent applications including all non–pledged patents. The matching process for Dutch data is currently under progress. Hence, the empirical analysis of this interim report will only focus on Swedish data.

Finally, we have generated two panel databases separate for the patent and firm level covering the years 1998 – 2015. First, the panel databases on the patent–level covers all pledged and non–pledged patents together with annual firm level data of pledging and non-pledging firms. This database is used to analyse patent characteristics which determine their collateralization.

Secondly, the panel database at the firm–level contains detailed financial data together with the firms' stock of patents and pledged patents on a yearly basis. The firm–level data is used to analyse the impact of patent pledging on firms' access to finance by using the (change in) debt levels.

All patent data have been supplemented with information from the EPO's patent statistical database (PATSTAT).

2 Patent Pledging in Sweden and the Netherlands

2.1 introduction

In perfect capital markets firms' investment decisions are supposed to be independent of their financial condition since external funds provide a perfect substitute for internal capital (Modigliani & Miller 1958). However, such conditions are of theoretical nature and rarely hold in practice. In the presence of asymmetric information between firms and investors, even profitable investment projects may not receive external finance (Stiglitz & Weiss 1981, Myers & Majluf 1984). Especially the financing of R&D projects is subject to asymmetric information due to the uncertain outcome and the problem of appropriability of resulting knowledge (Hall & Lerner 2010). However, many innovative firms have patents that can serve as loan collateral and therefore ease the access to external finance. This mechanism of patents in mitigating financing constraints has been widely overlooked in the literature and in practice. It can be assumed that not all patents qualify for loan collateral due to the skewed distribution of patent values (Scherer 1965). Hence, firms, investors and policy makers have a strong interest to know about patent characteristics facilitating their collateralization. If patents could be used more extensively as collateral, policy makers may not have to subsidize R&D activities of firms as much as in current practice in many EU Member States and other OECD countries (Czarnitzki et al. 2007). This could free up resources for other welfare enhancing policies.

Fischer & Ringler (2014) analyze characteristics of pledged US patents. They find that technology-related patent characteristics matter for patent pledging in the United States. Similarly, Mann (2018) shows that patents of higher quality, measured by the number of forward citations, as well as less firm-specific patents with a high number of alternative users are more likely to be pledged. Moreover, he shows that pledged patents significantly rise debt finance which contributes to subsequent innovation activities of those firms as well. Hochberg et al. (2018) show a positive impact of the US patent market liquidity on the patent collateralization in their empirical analysis. Summarized, current findings indicate that the quality of patents and a well developed secondary market for patents play a significant role when pledging patents. However, current studies focus on US patents pledged in the United States that are different to European economies. First, Europe's industry which is dominated by SME's and has a deficit in venture capital suggests stronger financing constraints for small and innovative firms (Hall et al. 2016, Revest & Sapio 2012). Second, the market for technologies are further developed in the United States (Arora & Gambardella 2010) having implications on liquidation values of pledged assets as explained below. Thus, this paper aims to provide evidence for patent characteristics of pledged patents in Europe. Moreover, it strongly links to collateral theory in the financial literature providing a more complete picture on which patent

characteristics determine their collateralization.

The finance literature defines the liquidation value of the pledged asset as the main determinant for the decision to secure loans by collateral (Williamson 1988, Shleifer & Vishny 1992). Thereby, the liquidation value depends on the quality of the pledged asset as well as its salability, i.e. the value an asset retains in liquidation (Benmelech 2008). The salability of an asset depends first, on its firm–specificity, since less firm–specific assets have many alternative users (Williamson 1988). Second, salability depends on the financial strength of alternative users who need to have the resources to buy the pledged asset in liquidation (Shleifer & Vishny 1992). In summary, the three factors "physical attributes of the asset", "firm-specificity of the asset" and "financial strength of alternative users" determine the liquidation value, which in turn, is the main driver for loan collateral. Thus, patent characteristics related to the three factors of collateralization should determine their chances of being pledged in loan negotiations.

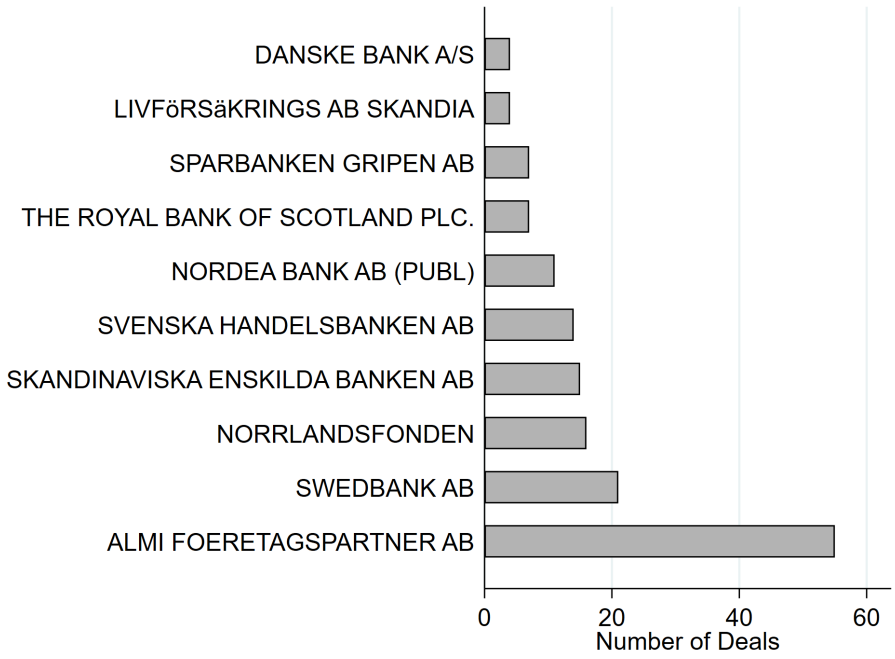
2.2 Descriptive Analysis

Overall 1,287 Swedish national patents and EP-patents valid in Sweden have been pledged by 644 entities between 1981 – 2015. The following descriptive statistics at the patent and firm level refer to sample data of 741 pledged patents by 201 Swedish firms between 1998 and 2015. Figure 2a shows that most pledging deals have been done with the state–owned developing bank Almi AB followed by the four major banking groups (Handelsbanken AB, Nordea Bank AB, Skandinaviska Enskilda Banken AB and Swedbank AB) dominating the Swedish financial market for years (Ekman et al. 2014).

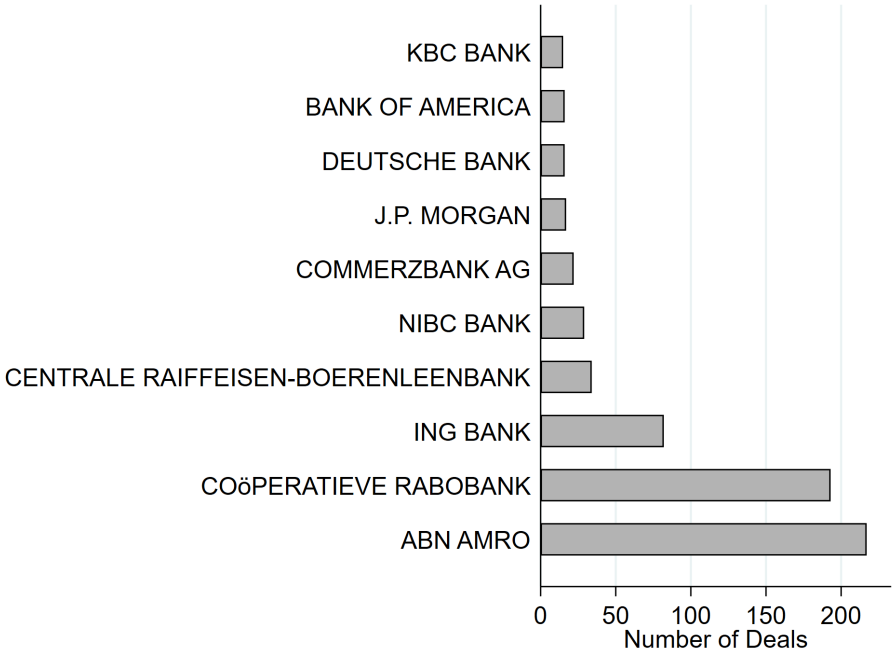
In the Netherlands the most active banks with regard to accepting patents as collateral are ABN Ambro, Rabonbank and the ING bank (see Figure 2b).

The majority of patents used for loan collateral have been pledged in a period of 10 years after the date of filing (Figure 3a and 3b). This is not surprising considering the fact that younger patents provide more time to possibly obtain (monopoly) profits, and thus have higher potential collateral value.

Moreover, pledged patents show more forward citations and higher numbers of family members than the average patent owned by Swedish firms (Figure 4). Both indicators may be used as proxy for the quality of the underlying technology (Harhoff et al. 2003), and thus indicate a higher value for pledged patents. We oberve similar patterns in the Dutch data, except that among the EP-patent applications the pledged patents do not seem to have significantly more family members than non-pledged patents (see Figure 5).

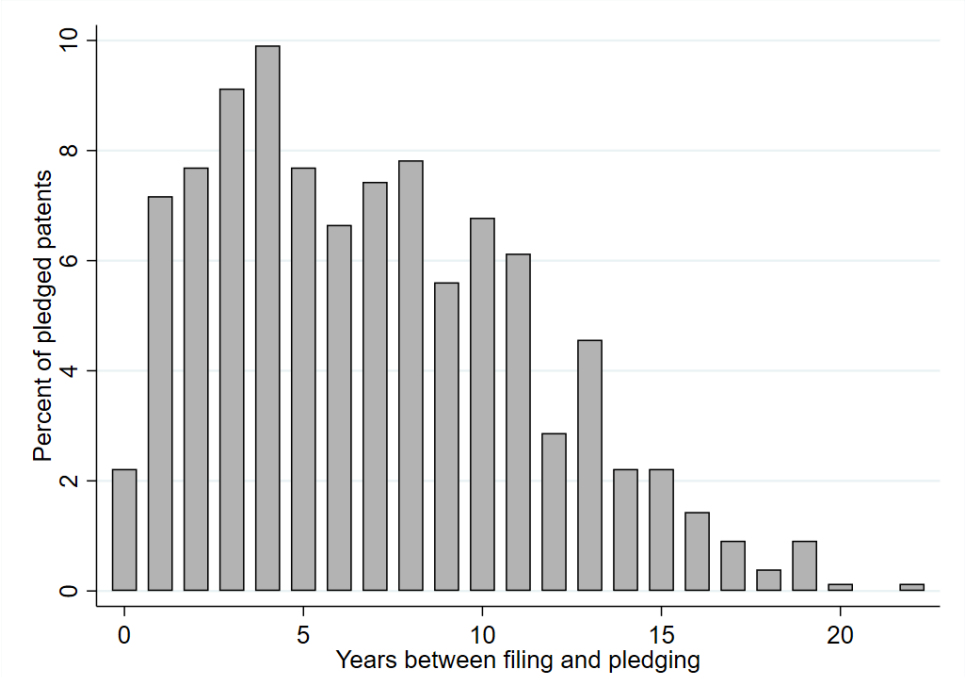


(a) Sweden

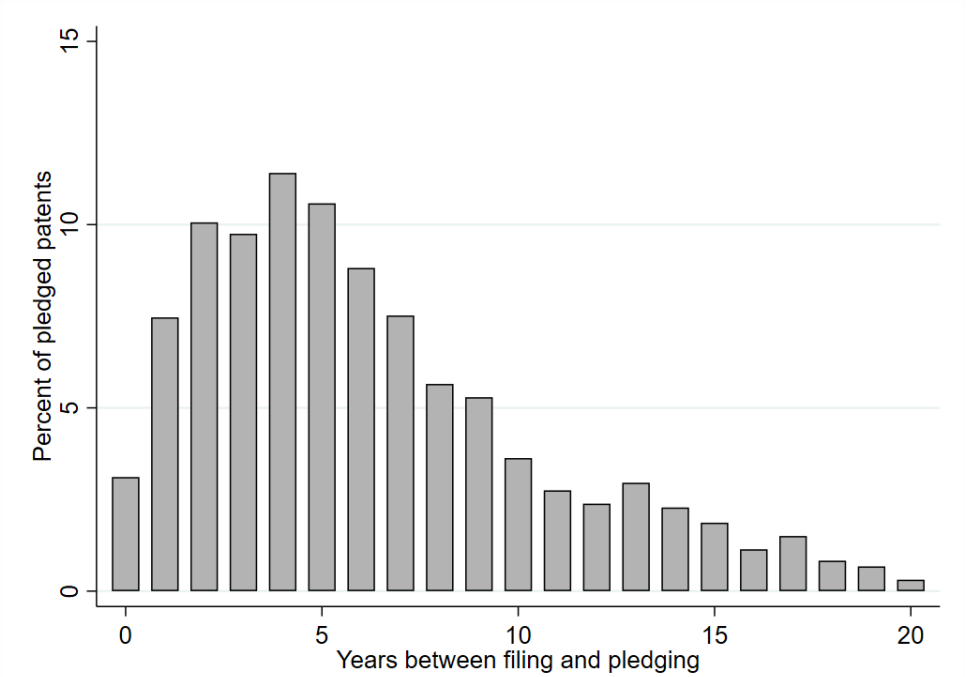


(b) Netherlands

Figure 2: Top 10 pledge holders.

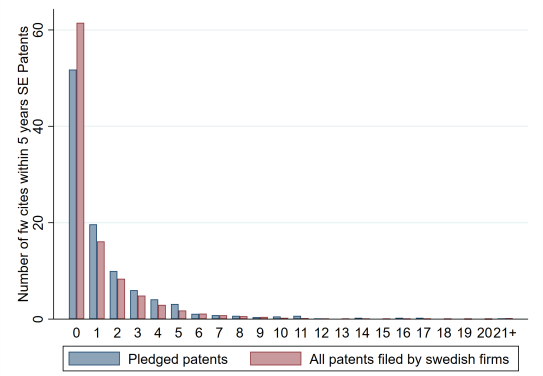


(a) Sweden

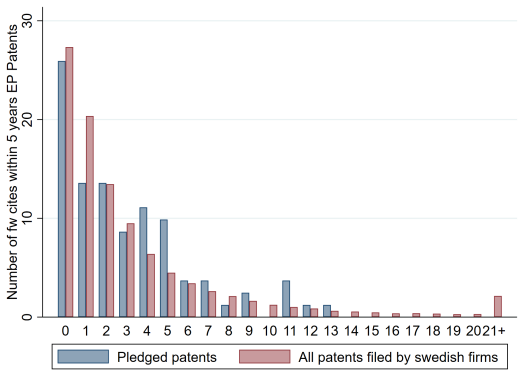


(b) Netherlands

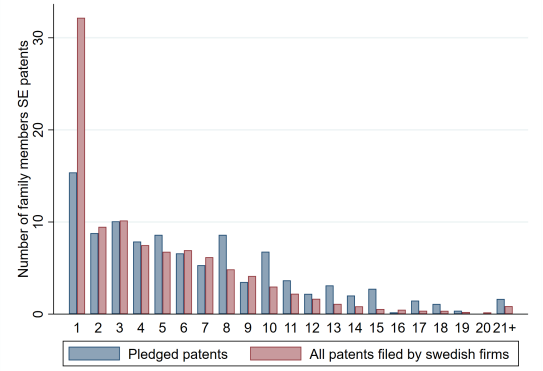
Figure 3: Years between patent filing and pledging.



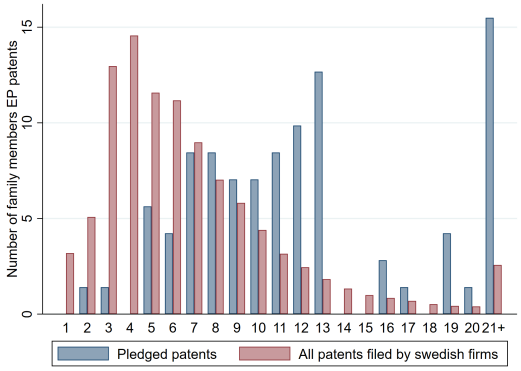
(a) Number of forward citations of SE-Patents



(b) Number of forward citations of EP-Patents



(c) Number of family members of SE-Patents



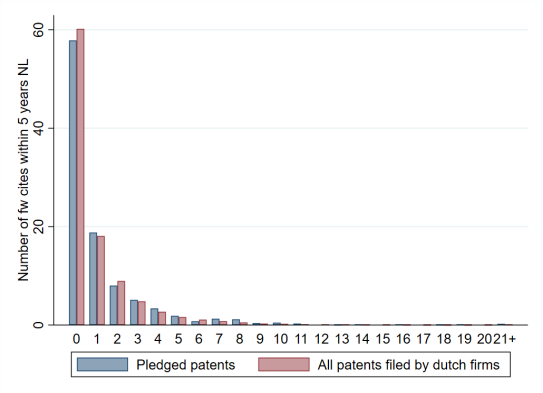
(d) Number of family members of EP-Patents

Figure 4: Number of forward citations and family members for pledged and entire patent population in Sweden.

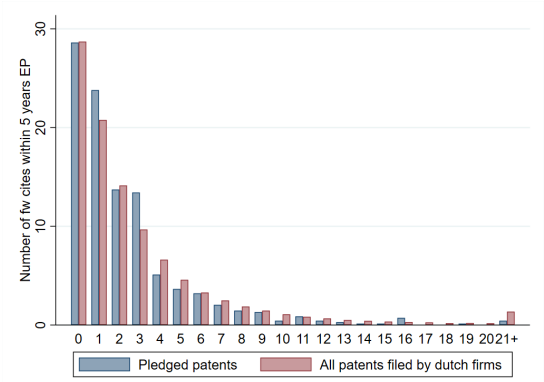
Taking a look at the firm characteristics, almost 60% of the firms in Sweden are younger than 10 years at the pledging date and almost 80% are small firms with less than 50 employees (Figures 6a and 6b). Those firm characteristics are in accordance to prior findings which show that small and young firms are affected by capital restrictions and at the same time driving the most radical innovations (Kerr & Nanda 2015, Brown et al. 2009). Thus, they might use their patents to overcome financing constraints.

In the Netherlands, the pledging firms are, on average, older than in Sweden (see Figure 7a), and also larger (see 7b).

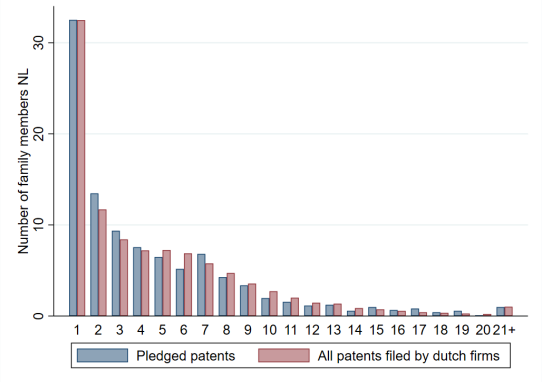
We also looked at the geographic distribution of patenting firms in Sweden and the Netherlands but did not find any significant geographic pattern of pledgors when compared to non-pledging patenting firms (see Figure 8).



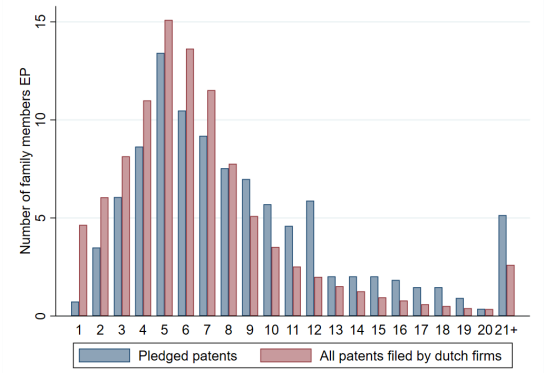
(a) Number of forward citations of NL-Patents



(b) Number of forward citations of EP-Patents

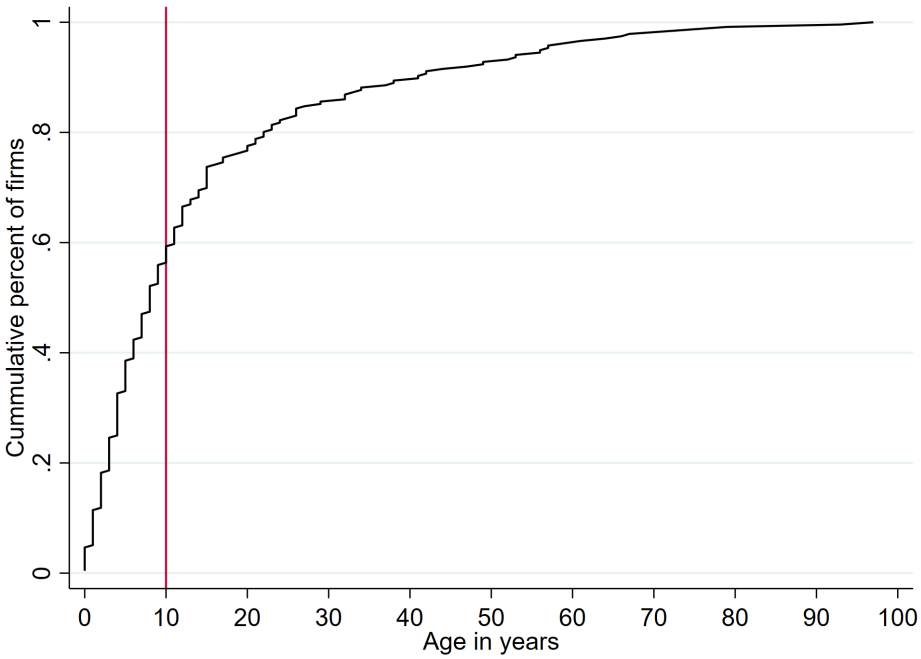


(c) Number of family members of NL-Patents

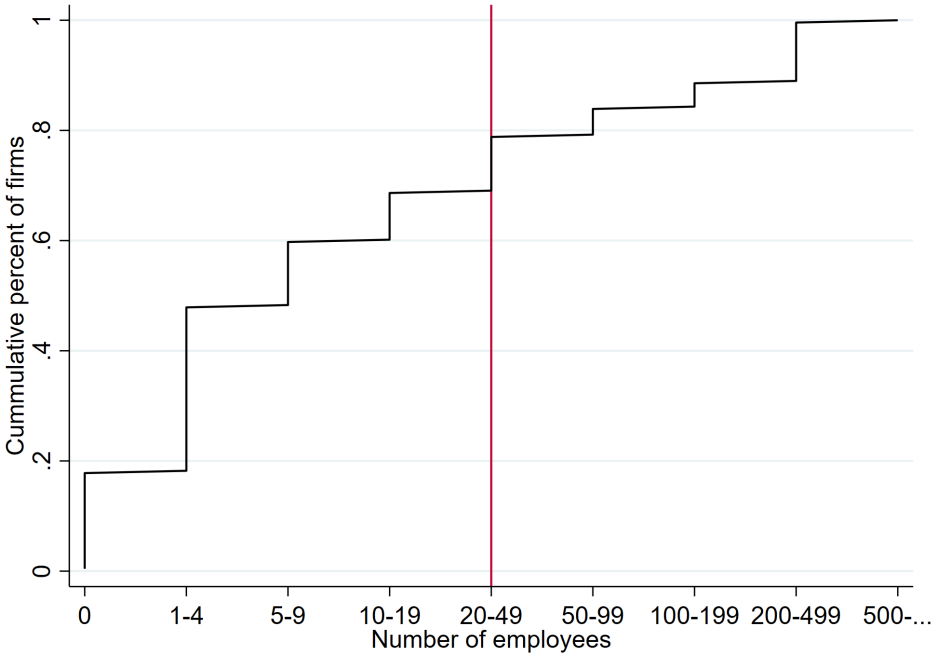


(d) Number of family members of EP-Patents

Figure 5: Number of forward citations and family members for pledged and entire patent population in the Netherlands.

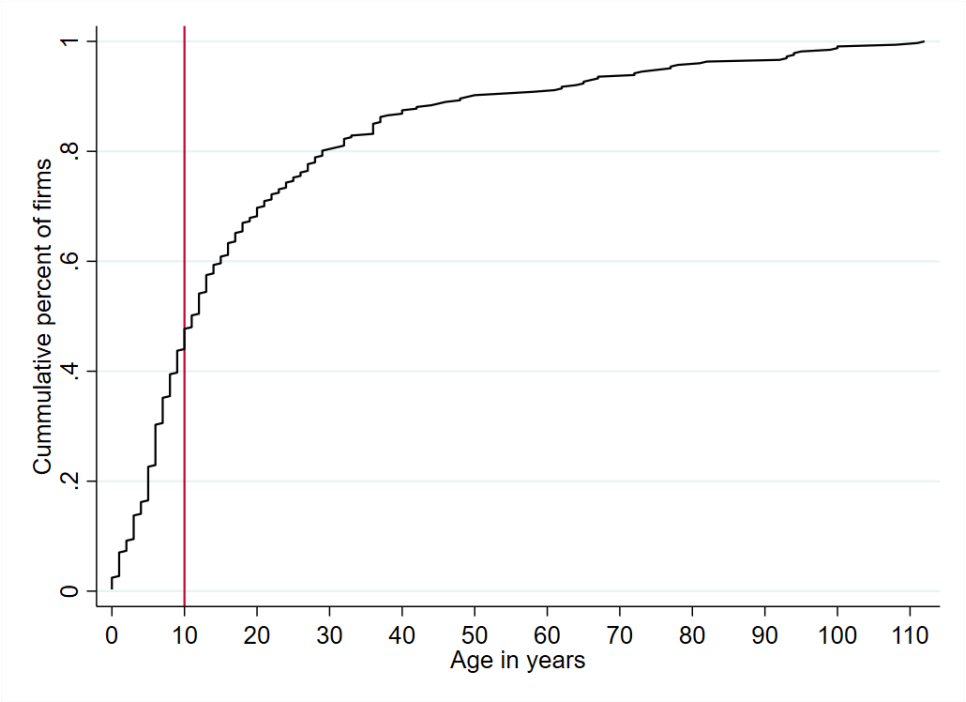


(a) Age of firm that pledge patents

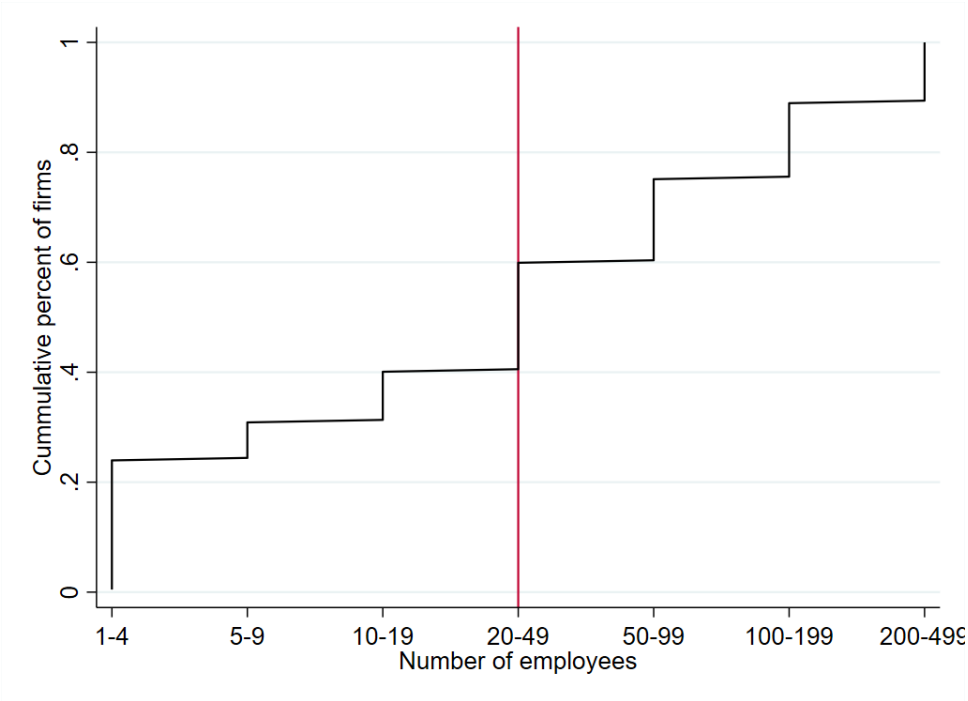


(b) Size of firms that pledge patents

Figure 6: Firm characteristics of patent pledging firms in Sweden.

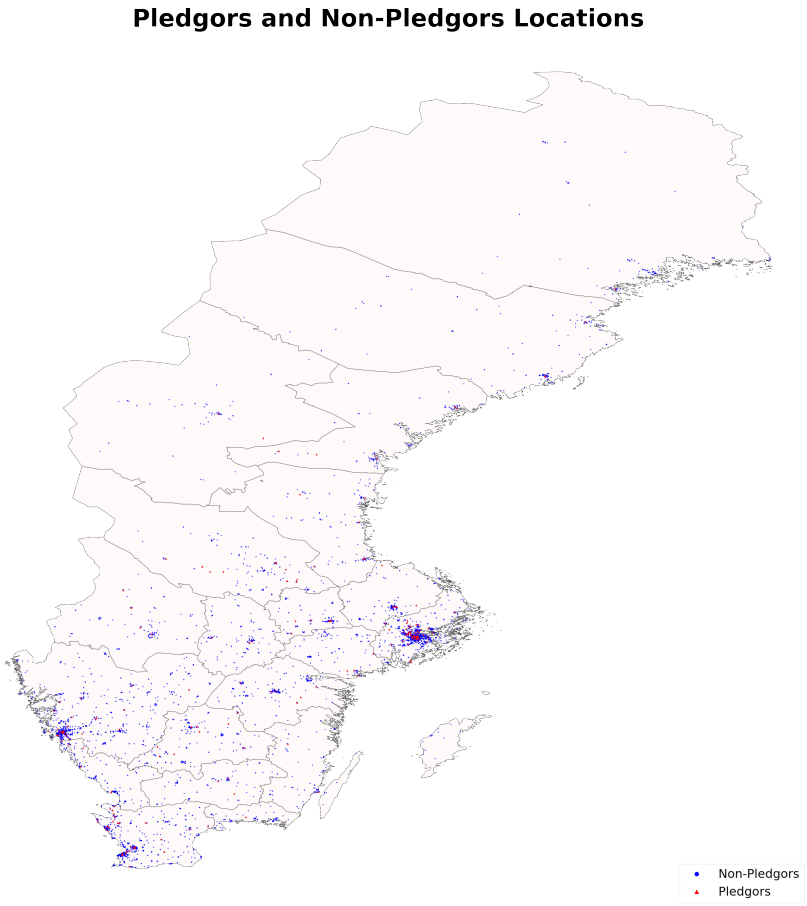


(a) Age of firm that pledge patents

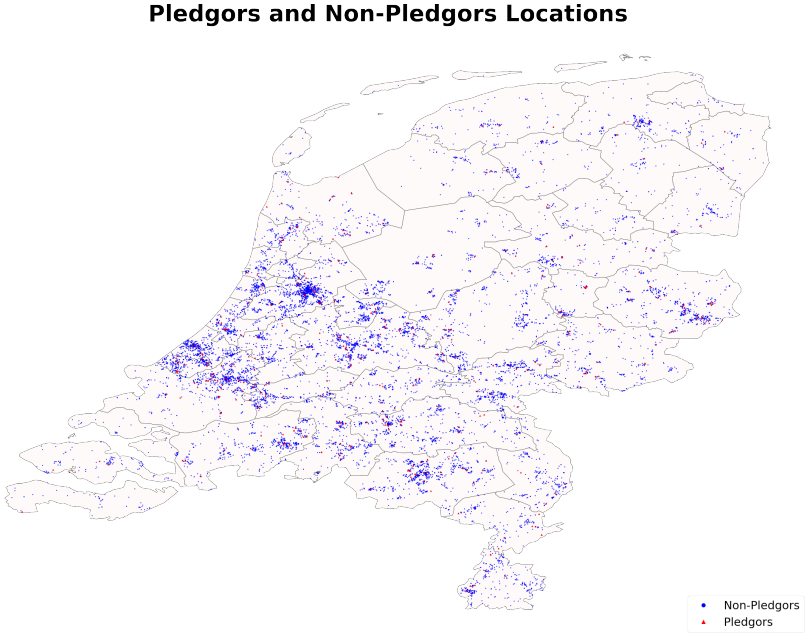


(b) Size of firms that pledge patents

Figure 7: Firm characteristics of patent pledging firms in the Netherlands.



(a) Sweden



(b) Netherlands

Figure 8: Location of patenting firms

2.3 Econometric Methodology

To investigate which patent characteristics matter for collateralization, we use two different identification strategies. First, we estimate Probit regressions comparing pledged and non–pleded patents within the same firm. By that, selection effects based on firm characteristics will be purged out. This is important since collateralization may be endogenous to the characteristics of the pledgor. Second, as an alternative procedure, we apply a non–parametric matching approach where we match patents that have been pledged based on firm characteristics to non–pledged patents, i.e. we compare pledged and non–pledged patents across observably similar firms.

2.3.1 Probit Regression

The empirical model is specified as following:

$$\Pr(Y_{ift} = pledged \mid X_{it}) = \Phi\left(\beta_1 X_{it} + \alpha_f\right) \tag{1}$$

The dependent variable Y_{ift} is a dummy variable capturing if a patent i has been pledged by firm f in year t. X_{it} is a vector of patent characteristics related to the three factors of collateralization described in section 2.1 and will be operationalized as described in the subsequent subsections.

Attributes of patents Two dummy variables indicate whether a patent has been granted and whether it is part of a triadic patent family. Patents that have not been granted yet bear the risk of subsequent refusal, and are therefore less valuable as collateral. Patents being part of a triadic family may indicate high commercial value of the underlying technologies (Grupp et al. 1996). Furthermore, we include the weighted share of forward citations within a 5-year window[1]. The more subsequent patents citing the pledged patent, the higher its technological relevance and hence, its quality. Similarly, we include the total number of family members. Furthermore, the larger the number of designated states of an EP–patent is, the higher may be the commercial value of the underlying technology. Last, we include the age of a patent since younger patents provide more time to exploit monopoly profits and hence have an higher remaining collateral value.

Firm-specificity of the patent The share of self-citations per patent. Self-citations to own patents may reveal firm specific technologies, since the invention may be based to a large extent on the firm's own, accumulated knowledge base. Firm-specific technologies are expected to have a limited number of alternative users and are thus possibly less

[1]Forward citations are weighted by the average number of forward citations of a patents with same filing year and technological field.

suitable for collateral. Moreover, we include commonly used measures for the originality and generality of a patent (OECD 2009). Those measures capture if a patent cites or was cited by patents that belong to a broad or narrow set of technologies. Similarly, we expect a reduced number of alternative users for patents protecting a narrow set of technologies.

Financial strength of alternative users The number of firms filing patents in the same technological field and year. Firms that file patents in the same technological field are the most likely buyers of the pledged patent, since those exploring the benefits from the redeployability most. Furthermore, we include the share of traded patents within a 3-year window of patents in the same technological field. The more patents have been traded relative to the total number of available patents, the higher the probability to sell pledged patents in that market, localized by the technical field of a patent.

Last, we include firm–fixed effects α_f to eliminate any unobserved effects between the firms pledging patents, fixed effects for the filing year and patent authority since EP and national SE patent follow different trends in time (Granstrand & Holgersson 2012).

2.3.2 Matching

As an alternative identification strategy, we compare pledged and non–pledged patents across similar firms with respect to their financial situation determining firms' demand for loan. Specifically, we apply a nearest neighbor Mahalanobis distance match on employees, firm age, debt to equity ratio, the share of intangible assets and firms cash-flow per assets for firms active in the same industry and year. Additionally, we do an exact match for the authority to which a patent has been filed, because EP- and SE-patents follow different trends in time. We match on patent owners' size and age because both measures are an important determinants for financing constraints (Hadlock & Pierce 2010). Debt to equity takes firms debt level into account. Furthermore, tangible assets over total assets is a common proxy for collateral which may influence firms' credit status (Almeida & Campello 2007). Last, we match on cash-flow to total asset to take firms internal financial capabilities into account (Fazzari & Petersen 1993). Focal patent characteristics are the same described in section 2.3.1 above.

2.4 Results on pledged patent characteristics

2.4.1 Descriptive statistics

Table 1 shows the summary statistics for the sample of pledged and non-pledged patents in Sweden. The sample includes 382 pledged patents and 853 non-pledged patents owned by 71 firms of which each firm has at least one pledged and one non–pledged patent. Patents have been pledged for the period 1999 until 2015. The sample includes only the first pledged patent per firm since subsequent patent pledging of firms might be endogenous. Similarly, only the first pledging event per patent will be considered in case a patent was sold after a pledging event and was subsequently pledged by the new owner of the patent. Table 2 shows the equivalent statistics for the Netherlands.

Table 1: Summary Statistics Sweden: Pledged and non-pledged patents

	N	Mean	SD	1%	99%
nb. applicants	4064	1.058	0.270	1.000	2.000
nb. inventors	4064	1.898	1.453	1.000	7.000
granted	4064	0.490	0.500	0.000	1.000
triadic	4064	0.357	0.479	0.000	1.000
fw. cites	4064	0.490	0.861	0.000	4.084
nb. fam. members	4064	6.155	7.781	1.000	23.000
patent age	4064	6.793	5.818	0.000	20.000
share self-cites	4064	0.005	0.026	0.000	0.091
generality	2046	0.480	0.319	0.000	0.905
originality	3129	0.585	0.267	0.000	0.922
nb. filing firms	3911	11.673	21.996	0.000	107.000
share patent trades	3911	0.000	0.001	0.000	0.004
N	4064				

Summary statistics for all 427 pledged patents and 3636 non-pledged patents owned by 118 firms.

2.4.2 Probit Results

Table 3 shows the results for the Probit regressions estimating the likelihood of a patent being pledged within a firm for the Swedish sample. The first twelve columns show the regression results for each patent indicator individually to avoid multicollinearity problems. The last column shows results for several patent indicators used simultaneously.

All patent indicators measuring the patent attributes show positive signs and are highly significant at the 1% level. The grant of a patent (*granted*), the number of forward citations ($fw.\ cites\ 5y$) or the number of family members ($Lg\ (fam.\ members)$) increase the likelihood of patents being pledged. The age of a patent shows inverse-U relationship

Table 2: Summary Statistics Netherlands: pledged and non-pledged patents

	N	Mean	SD	1%	99%
nb. applicants	4524	1.054	0.276	1.000	2.000
nb. inventors	4524	2.228	1.568	0.000	7.000
granted	4524	0.775	0.417	0.000	1.000
triadic	4524	0.357	0.479	0.000	1.000
fw. cites	4524	0.467	0.694	0.000	3.311
nb. fam. members	4524	6.843	9.934	1.000	36.000
patent age	4524	6.313	4.964	0.000	19.000
share self-cites	4524	0.007	0.028	0.000	0.125
generality	2685	0.572	0.305	0.000	0.922
originality	4188	0.647	0.250	0.000	0.935
nb. filing firms	3812	13.710	18.675	0.000	91.000
share patent trades	3812	0.000	0.000	0.000	0.000
N	4524				

Summary statistics for all 1220 pledged patents and 2985 non-pledged patents owned by 245 firms.

with the likelihood of being pledged. The inverse U-shape peaks at about the age of 6 years after application. Considering the average application to grant time of about 3.5 years, on average, the curve roughly coincides with the theory on the redeployability of the pledged asset. As the granted patent loses value as time elapses, the likelihood that it is pledged, i.e. accepted as collateral, reduces.

Most patent indicators measuring whether the patent protects firm-specific technologies are insignificant including originality and generality. The share of self-citations ($share\ self-cites$) shows a negative sign in the regression without further covariates. However, the sign of the coefficient switches, once we condition on measures for the attributes of the patent. Thus, the results are not robust across different specifications.

Last, both patent indicators approximating the financial strength of alternative users are insignificant. Neither, the number of firms filing patents in same technical fields ($nb.\ filing\ firms$) nor the share of patent trades within a patents' technical fields ($patent\ trades$) have an impact on the likelihood of the focal patent being pledged.

Very similar results are obtained for the Dutch sample (see Table 4).

Table 3: Sweden: Probit regression estimating the likelihood of a patent being pledged

Dep. Variable:	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged
nb. applicants	-0.81**												-0.97***
	(0.25)												(0.27)
nb. inventors		-0.00082											-0.017
		(0.027)											(0.037)
granted			1.03***										0.91**
			(0.27)										(0.30)
triadic				0.33**									
				(0.12)									
fw. cites					0.15**								0.097
					(0.054)								(0.050)
Lg (fam. members)						0.35***							0.18*
						(0.087)							(0.088)
Lg (patent age)							1.59***						
							(0.47)						
Lg (patent age)^2							-0.30*						
							(0.14)						
nb. filing firms								-0.0012					-0.0035
								(0.0021)					(0.0025)
$share\ self-cites$									0.25				-0.18
									(1.36)				(1.49)
originality										-0.071			
										(0.25)			
generality											0.19		
											(0.32)		
patent trades												-239.5**	-98.4
												(80.5)	(81.9)
Patent Auth. FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Filing Year FE	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	3652	3652	3652	3652	3652	3652	4062	3515	3652	1964	1230	3515	3515

Clustered at firm level

*, **, and *** represent significance at the 10%, 5%, and 1% level, respectively.
Robust SE

Table 4: Netherlands: Probit regression estimating the likelihood of a patent being pledged

Dep. Variable:	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged	Y=pledged
nb. applicants	-0.70***												-0.81***
	(0.16)												(0.18)
nb. inventors		0.11***											0.12***
		(0.024)											(0.024)
granted			1.25***										1.09***
			(0.17)										(0.17)
triadic				0.24**									
				(0.086)									
fw. cites					0.23***								0.15**
					(0.046)								(0.049)
$Lg\ (fam.\ members)$						0.29***							0.21***
						(0.043)							(0.063)
$Lg\ (patent\ age)$							1.38***						
							(0.33)						
$Lg\ (patent\ age)^2$							-0.42***						
							(0.077)						
$nb.\ filing\ firms$								-0.0062*					-0.0072*
								(0.0027)					(0.0029)
$share\ self-cites$									1.34				0.83
									(0.84)				(1.03)
originality										-0.12			
										(0.15)			
generality											0.083		
											(0.16)		
patent trades												1625.7***	1227.8***
												(334.5)	(286.7)
Patent Auth. FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Filing Year FE	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	4485	4485	4485	4485	4485	4485	4524	3806	4485	4117	2462	3806	3806

Clustered at firm level

*, **, and *** represent significance at the 10%, 5%, and 1% level, respectively.
Robust SE

2.4.3 Matching Results

Table 5 shows the average values of all variables for the Swedish sample of pledged and unpledged patents prior to the matching process and also afterwards. Before the matching, the mean values of almost all firm characteristics and patent characteristics are statistically different between the groups. Firms that pledged patents have on average less employees and are younger. This is in accordance to descriptive findings in section 2.2. Furthermore, the sample of unpledged patents shows that pledgors have on average a higher level of intangible assets and less internal sources of finance (cash-flow/assets) than firms of unpledged patents. Consequently, firms with less tangible assets and lower internal sources of finances might pledge patents to satisfy their financial demand.

To balance the distribution of firm characteristics between pledged and unpledged patents, we apply a nearest neighbor Mahalanobis distance match on employees, firm age, debt to equity ratio, the share of intangible assets and firms cash-flow per assets for firms active in the same industry and year. Additionally we do an exact match on patents authority to control for any permanent differences between SE- and EP-patents. Table 5 shows the summary statistics after the matching process. There is no significant difference between the pledged and unpledged patents for the matched variables. Consequently, the samples of pledged and matched unpledged patents are observably similar with respect to patent owners' characteristics determining the decision to seek additional capital by using patents as collateral. However, all measures for patents quality remain significant different between the groups. Pledged patents are, on average, more often granted and more often part of a triadic family. Moreover, pledged patents have, on average, more forward citations and family members. The age of pledged patents are on average not significantly different from unpledged counterparts. Results of the Probit regressions revealed a non–linear relationship where the likelihood of patents being pledged increases by age with a decreasing rate. Thus, on average the age might not be significantly different between the groups.

Most patent indicators measuring whether the patent protects firm-specific technologies are insignificant including the share of self-citations and generality. Pledged patents have on average a lower originality index thus might cite patents with narrower technological field than unpledged counterparts. However, the relevance of patents originality for collateralization cannot be confirmed in the Probit regression. Overall, we find no evidence that patents protecting firm-specific technologies are less suited for loan collateral.

Last, there are mixed results for patent indicators approximating the financial strength of alternative users. Pledged patents are filed in technological fields that have on average a higher patenting activity. However, these findings cannot be confirmed in the Probit regressions. Moreover, there is no significant difference in the share of traded patents within patents' technological fields between pledged and unpledged patents. Thus, we

cannot confirm that financial strength of alternative users matters for patent pledging.

Again, the results for the Netherlands are very comparable to the Swedish ones (see Table 6).

Table 5: Sweden: Matching Results

	Unmatched Sample			Matched Sample		
	Pledged Patents	Non-Pledged Patents	p>|t|	Pledged Patents	Non-Pledged Patents	p>|t|
firm age	27.158	62.715	0.000	27.276	27.463	0.912
debt/ equity	3.496	1.795	0.000	3.499	3.350	0.592
intang./ asstes	0.125	0.128	0.553	0.125	0.123	0.791
cash-flow/ asstes	1.506	2.138	0.001	1.512	1.462	0.847
patentstock	20.928	1441.070	0.000	20.979	7.856	0.000
nb applicants	1.014	1.050	0.000	1.019	1.061	0.029
nb inventors	1.726	2.068	0.000	1.734	1.554	0.012
granted	0.826	0.615	0.000	0.829	0.563	0.000
triadic	0.386	0.400	0.547	0.388	0.241	0.000
fw cites	0.442	0.452	0.782	0.444	0.244	0.000
nb fam members	7.140	7.168	0.907	7.168	4.918	0.000
patent age	6.858	8.514	0.000	6.813	8.266	0.000
firm specifity	0.005	0.006	0.420	0.005	0.001	0.013
generality	0.519	0.574	0.006	0.519	0.529	0.742
originality	0.587	0.656	0.000	0.587	0.618	0.138
nb filing firms	12.829	22.195	0.000	12.829	12.071	0.622
share patent trades	0.000	0.000	0.003	0.000	0.001	0.000
N	430	798143		428	428	

This table presents the summary statistics for the unmatched and matched samples of pledged and non-pledged patents. We apply a Mahalanobis Distance match on firm characteristics of the patent owning firms including firm age, debt-to-equity ratio, share of intangible assets, and chash-flow to asstes ratio. Additionaly, we apply an exact match for the year of financials and patent filing authority. All monetary values are in thousands euro.
*, **, and *** represent significance at the 5%, 1%, and 0.1% level, respectively.

Table 6: Netherlands: Matching Results

	Unmatched Sample			Matched Sample		
	Pledged Patents	Non-Pledged Patents	p>|t|	Pledged Patents	Non-Pledged Patents	p>|t|
firm age	24.746	81.122	0.000	24.789	26.191	0.337
debt/ equity	3.424	1.689	0.000	3.227	2.853	0.214
intang./ asstes	0.205	0.161	0.000	0.205	0.201	0.631
cash-flow/ asstes	1.013	0.806	0.007	0.957	1.011	0.592
patentstock	17.651	4123.322	0.000	17.703	3.311	0.000
nb applicants	1.043	1.227	0.000	1.043	1.104	0.000
nb inventors	1.994	1.991	0.959	1.996	1.452	0.000
granted	0.920	0.551	0.000	0.921	0.794	0.000
triadic	0.234	0.624	0.000	0.235	0.127	0.000
fw cites	0.335	0.431	0.000	0.335	0.205	0.000
nb fam members	5.301	6.641	0.000	5.310	4.092	0.000
patent age	6.155	9.380	0.000	6.168	7.773	0.000
firm specifity	0.008	0.010	0.236	0.008	0.006	0.260
generality	0.482	0.545	0.000	0.484	0.474	0.676
originality	0.592	0.629	0.000	0.592	0.575	0.231
nb filing firms	10.500	17.626	0.000	10.529	9.447	0.166
share patent trades	0.000	0.000	0.912	0.000	-0.000	0.168
N	930	1049678		927	927	

This table presents the summary statistics for the unmatched and matched samples of pledged and non-pledged patents. We apply a Mahalanobis Distance match on firm characteristics of the patent owning firms including firm age, debt-to-equity ratio, share of intangible assets, and chash-flow to asstes ratio. Additionaly, we apply an exact match for the year of financials and patent filing authority. All monetary values are in thousands euro.
*, **, and *** represent significance at the 5%, 1%, and 0.1% level, respectively.

2.5 Conclusion

Our study explores patent characteristics facilitating pledging in Sweden and the Netherlands. Such patent characteristics may be of interest for firms (both lenders and borrowers) and policy makers to better understand how patents can ease the access to external finance. In accordance to the financial literature three factors "physical attributes of the asset", "firm-specificity of the asset" and "financial strength of alternative users" determine the liquidation value, which in turn, is the main driver for loan collateral. Hence, we exploit several patent indicators which measure first, patents quality, second firm-specificity of underlying technology and third, the financial strength of a patents alternative users. To identify the relevance of the patent indicators on the decision to pledged patents, we use two different empirical models that mitigate selection effects by firms pledging patents. First, we estimate a Probit model comparing pledged and unpledged patents within firms. Second, we compare pledged and unpledged patents across a matched sample of observably similar firms.

We find strong evidence that patents quality matter for collateralization. Results in the Probit regression as well as the matched sample show that more forward citations, family members and granting of patents increases patent pledging. Interestingly, we find some evidence for a inverse-U relationship between the age of a patent and its likelihood of being pledged. This finding can be explained by the time required for the granting process. Following the granting patents value as collateral decreases with its age. However, we do not find support that patents protecting firm-specific technologies are less suited for collateral. Neither do we find evidence that the financial strength of alternative users matter for pledged patents. Both factors are important determinants for the salability of an assets. Hence, pledgees might not take the salability of patents into account. This might be due to the underdeveloped market for intellectual property in Europe (Arora & Gambardella 2010). Thus, it will be hard for banks and investors to identify a secondary market for pledged patents. Instead, pledgees are focusing on easily observable patent characteristics indicating a high value for the collateral.

Nevertheless our results come with some limitations. Patent pledging is not a random process and endogenous to unobservable firm characteristics that we cannot take into account for our matching process.

3 Patent Pledging and Access to Debt

3.1 Introduction

Innovation is an important source of economic growth, especially for developed countries (Romer 1990, Aghion & Howitt 1990). However, investments in research and development (R&D) are hampered by capital restrictions (Nelson 1959, Arrow 1972). Given the inherent uncertainty of R&D projects, R&D performers are better informed about the expected outcome of their R&D projects than potential lenders. This information asymmetry can raise transaction costs to an extent that socially desirable innovation projects are not implemented as the cost of external capital rendered them privately unprofitable (Hall & Lerner 2010). Therefore, many innovative companies are financially constrained (Czarnitzki & Hottenrott 2011).

The current literature on financing constraints is mainly focused on establishing empirically the existence on financing constraints, and to lesser extent on how to mitigate them. Examples of the latter are analyses of the institutional framework, e.g. banking practice, and the relationships between firms and investors (Beck et al. 2007). Czarnitzki & Hottenrott (2017) have suggested that management practices in form of R&D collaboration may help to attenuade financing constraints. Intellectual assets such as patents documenting past successful inventive activity can also mitigate financing constraints. Hottenrott et al. (2016) show that patents reduce financing constraints by disclosing information to investors, described as the signaling value of patents. In addition to the signalling value of patents, however, firms can also pledge patents for loan collateral to ease access to finance. This channel has attracted surprisingly little attention in the empirical literature.[2] The theoretical literature points out that investors can use collateral as a screening device that mitigates adverse selection (Bester 1985). Hence, patents pledged as collateral, provide incentives for lenders to commit funding and, at the same time, leave the ownership of patents to borrowers (Steijvers & Voordeckers 2009). Moreover, the loss of importance of tangible assets in modern knowledge economies (Goldfinger 1997) forces firms to resort to intangibles for collateral.

In this paper, we estimate treatment effects of patent pledging on the pledgor's access to external capital as measured by debt at the firm level. We obtained information on all pledged patents in Sweden and the Netherlands and constructed panel databases including financial data. Conditional Difference-in-difference (CDID) analyses for matched samples of similar non-pledging Swedish and Dutch firms reveal significant increase in the levels of debt following the pledging event. Estimated results show that the patent pledging

[2]One might also think of selling or licensing patents. However, in both cases firms will lose their patent or reduce its competitiveness. Moreover, small firms which are mostly affected by financing constraints are less diversified, and could thus lose significant parts of their business model by selling / licensing patents.

event causes an increase in debt by about 34% for Dutch pawners and about 20% for Swedish pawners, respectively. These relative changes correspond to higher debt of about 1.4 million euro in the Netherlands and 1.2 million euro in Sweden. However, descriptive statistics show that only a few patenting firms in both countries pledge patents. A back-to-envelope calculation shows that patent owners could raise more than 5 billion euro in the Netherlands and more than 13 billion euro in Sweden if all firms pledge their complete patent portfolios, all else constant. Thus, patents pledged as loan collateral may provide a fruitful source of external financing.

Our regressions also allow comparing the signaling value and the collateral value of patents with regard to debt. We find that the patents' collateral value exceeds their signaling value for firms in the Netherlands but not for firms in Sweden.

Our findings contribute to the vast literature on financing constraints. Among others, Harhoff (2000) and Brown et al. (2009) provide evidence that innovative firms are financially constrained. Our results show that firms can access external finance by offering patents as loan collateral, hence mitigate financing constraints. Moreover, we contribute to the scarce literature on patent pledging. Mann (2018) provides descriptive evidence that mature US firms pledging patents as collateral have significantly higher total debt. Our results reinforce these findings in the framework of a treatment effects study with both public and private firms in Europe and suggest that collateralized patents causally help firms to access more debt. In addition, our findings can also be interpreted as a contribution to the large literature on patent valuation (Bloom & Van Reenen 2002, Hall et al. 2005, Czarnitzki et al. 2006, Gambardella et al. 2008). The estimated treatment effects reflect a minimum value of the pledged patent as lenders are willing to supply additional capital for these collateralized patents in loan contracts.

The rest of the paper is organized as follows: In Section 3.2 we explain our conceptual framework including the empirical identification strategy. In Section 3.3 we present a description of the data including data sources, descriptive statistics and the construction of a control group. Section 3.4 presents and discusses our findings. Finally, Section 3.5 concludes on implications of our results.

3.2 Conceptual framework and empirical identification strategy

We estimate the impact of patent pledging on firms' access to debt. Specifically, we apply a conditional difference-in-difference (CDiD) framework to estimate the treatment effect of patent collateralization in a loan negotiation. Thus, we compare the debt level of a firm after the event of a patent pledge with the debt level before this event. As the debt level might be affected by other exogenous macroeconomic characteristics relevant to the firm, we use non-patent-pledging firms as control group in the regression analysis.

To address the selection into the group of pawners, we perform matching to find

similar non-pledging firms that are comparable in the pre-treatment period. Specifically, we apply a Mahalanobis distance match in the pre–treatment period on debt, equity, the patent stock and the number of forward citations the firms' patent portfolio receives in the future as well as firms' age and sector. By conducting such a matching in the pre-treatment period, we establish a quasi–experimental setting in which the treatment group and the control group had, on average, in the past similar demands for debt and currently possess similar equity. Furthermore, the patent stock and the forward citations to this patent stock control for the potential collateral that the firms could offer to lenders in terms of quantity and quality of their intellectual assets. We thus interpret positive coefficients for the patent pledging event as estimates of the additional capital that firms could raise because of pleding patents.

We implement the Mahalanobis distance matching as nearest neighbor matching in which we draw up to two nearest neighbors per treated firm. We use a Calipre restriction to prevent bad matches, i.e. large Mahalanobis distances, which might introduce bias and draw the neighbors without replacement (Abadie & Spiess 2021).

In the following, we regress debt on a set of indicators for the periods pre- and post-pledging event for the matched sample. The change of patents collateral status allows controlling for firm-fixed effects. Therefore, any time-invariant firm characteristics, such as management quality or ownership structure, that may be related to firms' access to debt will be differenced out. The specification for the difference-in-difference regression is:

$$y_{it} = \sum_{k} \beta_1 PP_{it} + \beta_2 \boldsymbol{X_{it-1}} + \beta_3 \boldsymbol{d_t} + \alpha_i + \varepsilon_{it} \tag{2}$$

Specifying that $t = 0$ is the last pre-treatment period and thus also the period used for matching, the following timeline applies $t = (-2, -1, 0, 1, 2, 3, +4)$. y_{it} is the natural logarithm of firm i's debt in year t. $PP_{it} = 1$ if a patent has been pledged for all $k \geq t$ periods. $\boldsymbol{X_{it-1}}$ is a vector of time-varying firm-level characteristics that might influence access to debt. We use the one-year lag of firms equity controlling for differences in capital between pledging and non-pledging firms. We include the natural logarithm of firms' patent stock to capture patents' signaling value to investors (Hottenrott et al. 2016). Furthermore, we control for differences in firm size, measured by the natural log of employees, because it is an important determinant for financing constraints (Hadlock & Pierce 2010). Last, we include the natural logarithm of the average number of forward citations of firms' annual patent portfolios. This measure serves as a proxy for the quality of firms intangible assets. d_t are a set of time dummies capturing macro-economic changes, and α_i are firm-fixed effects capturing time-invariant differences across firms.

It is possible that the impact of patent pledging varies over time. Therefore, in a second step, we estimate a variation of Equation (1) with multiple pre-pledge and post-

pledge indicators for patent pledging firms. This is useful for gauging the overall pattern of the impact of patent collateral. In addition, the coefficients for the pre-pledge periods serve as direct test of the common trend assumption. We thus regress debt on a set of indicators for the years since any patents have been pledged, ranging from $t = -2$ to $t = +4$. The estimation equation is:

$$y_{it} = \sum_{\tau=-2,\tau\neq 0}^{+4} \gamma_\tau PP_{i\tau} + \beta_2 \boldsymbol{X_{it-1}} + d_t + \alpha_i + \varepsilon_{it} \tag{3}$$

$PP_{i\tau}$ is an indicator equal one if a firm pledged patents τ years after or $-\tau$ later if τ is negative, and zero otherwise. We include indicators for $\tau = -2$ before the pledging event up to 4+ years after the pledging patents. We omit the indicator the year before the pledging event ($\tau = 0$), so the estimated coefficients should be interpreted as the change relative to the year before the pledging event. Other specifications are identical to Equation 2 as described above.

The set-up of our matching routine and the fixed-effects within regression conforms to the recent suggestions of Abadie & Spiess (2021) who argue that standard errors in CDID applications are biased if the matching is not done without replacement and the subsequent regression does not include all covariates used for the matching. We therefore believe that we establish state-of-the-art inference.

3.3 Data sources and descriptive statistics

3.3.1 Data sources

The empirical analysis is based on detailed firm–level information covering balance sheet and income statement data combined with information on patents owned by the respective firms. Moreover, the analysis utilizes information on pledged patents. The registration of pledged patents is determined by the national patent law and is not mandatory in most countries. However, the Swedish and Dutch patent offices are one of the few national patent offices where the registration of collateralized patents is mandatory (Ministry of Justice Stockholm 1967*b*, The Minister of Justice Den Haag 1995). Thus, we restrict our sample to Swedish and Dutch firms.

To construct our data, we make use of the Orbis Global and Orbis IP databases combining rich firm-level and patent-level information. Importantly, Orbis does not only cover listed companies but also private firms. We obtained historical financial data together with filed patents for all Dutch and Swedish companies. Second, we gained access to detailed information about all pledged national patents and valid EP-patents from the Dutch and Swedish Patent Offices. The database contains information about the date the patent was pledged and the patent owner at the pledging date. Information on pledgors covers firm names and addresses, allowing us to match patent pledgors with

historical financial data and information on non-pledged patents from Orbis IP. Third, we gather data on the number of forward citations for all patents from PATSTAT.[3] The total number of forward citations that patents receive is a common proxy for the quality or technological importance of patents (Trajtenberg 1990, Hall et al. 2001). We average the number of forward citations over firms' annual patent stocks to proxy the quality of the entire patent portfolio.

Finally, we construct two separate panels for Swedish and Dutch firms, containing detailed financial data together with their stock of patents, the average number forward citations of the patent portfolio and the number of pledged patents on a yearly base.

The patent stock is constructed according to the pertpetual inventory method, i.e. it measures the accumulated yearly number of patent applications of the focal firm depreciated at a rate of 15 percent as common in the literature (Cuneo & Mairesse 1983).

3.3.2 Descriptive Statistics

We restrict our data to patenting firms, as non-patenting firms are considered irrelevant for the treatment effects analysis. Furthermore, we have dropped all sectors in which no firm pledged a patent in our period under review. Finally, all financial variables have been trimmed at the 1% level on each side of the distribution to eliminate influential observations.[4]

The final Dutch sample includes 8650 non-pledging firms and 186 patent-pledging firms observed between 1994 and 2018. Firms in the sample pledged patents between 1995 and 2017. In total, the Dutch panel contains about 100,000 firm-year observations. The Swedish sample includes 7226 non-pledging firms and 130 patent pledging firms observed between 1997 and 2018. Firms in the sample pledged patents between 1998 and 2016. For Sweden, our final data contains almost 90,000 firm–year observations.

Tables 7 and 8 show the summary statistics for the sample of Dutch and Swedish patent-pledging firms and patentees that do not pledge any patent, respectively. Patent-pledging firms in Sweden and the Netherlands show a similar age structure with an average of around 20 years. However, Swedish pledgors are larger then their Dutch counterparts, showing on average more employees and total assets. Non-pledging firms differ in all dimensions from firms offering patents for loan collateral, which suggest a selection of firms into the group of pawners. To address potential selection effects, we conduct a matching analysis to balance the covariates among the treatment and selected control group in the pre-treatment period.

[3]We normalize the total number of forward citations by the average number of citations patents receive with the same filing year and technical field.

[4]The debt variable has been trimmed at 2% level due to high number of outliers.

Table 7: Summary statistics for the Dutch sample

	Patent pledging firms					Non-pledging firms				
	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Total Assets	2124	18462.64	61351.94	1.72	855793.00	115603	14579.25	65996.05	1.39	976000.00
Debt	2048	9266.63	17142.16	0.16	142032.00	110190	4714.08	14114.39	0.10	160524.00
Equity	2043	6019.16	21469.21	-4080.92	385525.86	114255	5405.65	24919.37	-4088.00	406400.65
Employees	1372	128.31	379.16	1.00	5906.00	69976	90.15	437.53	1.00	40045.00
Age	2124	21.36	22.22	0.00	116.00	115576	21.81	22.99	0.00	314.00
Patentstock	2124	4.42	43.85	0.00	1121.30	115603	1.22	13.17	0.00	1035.30
Forward Cites	2124	0.27	0.35	0.00	2.39	115603	0.18	0.42	0.00	13.37
N	2124					115603				

8650 non-pledging firms and 186 patent pledging firms observed between 1994 and 2018. Firms pledge patents between 1995 and 2017. All monetary values are in Thd. Euros.

Table 8: Summary statistics for the Swedish sample

	Patent pledging firms					Non-pledging firms				
	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Total Assets	1855	48082.49	131429.22	5.61	890363.00	103974	13454.91	60470.71	5.18	949975.72
Debt	1698	12403.05	32087.86	1.02	204378.64	93344	5226.49	18060.90	0.87	204978.81
Equity	1756	16316.02	43700.68	-126.00	364397.19	102925	5356.02	23248.33	-129.52	372612.00
Employees	1750	171.12	514.39	0.00	4929.00	95691	64.64	336.70	0.00	40567.00
Age	1855	20.23	20.40	0.00	119.00	103974	21.44	19.38	0.00	120.00
Patentstock	1855	4.48	14.91	0.00	174.76	103974	1.25	6.46	0.00	410.56
Forward Cites	1855	0.36	0.38	0.00	2.76	103974	0.19	0.39	0.00	14.31
N	1855					103974				

7226 non-pledging firms and 130 patent pledging firms observed between 1997 and 2018. Firms pledge patents between 1998 and 2016. All monetary values are in Thd. Euros.

3.3.3 Matching

Tables 9 and 10 show the descriptive statistics for non-pledging firms and pledging firms in the year before patents have been pledged, i.e. the pre-treatment period. Both samples include only the first pledging event per firm since subsequent patent pledging of firms might be endogenous. The mean values of the debt variable and all covariates are statistically different between the groups in the unmatched samples (Tables 10 and 9). To balance the covariates between patent-pleding and non-pledging firms, we apply a Mahalanobis distance match on pre-treatment debt, equity, firm age, patent stock (and its square to assign more weight to this variable in the matching procedure), and the number of forward citations of firms' patent portfolios. We require an exact match on the economic sector and year. The matching is implemented as nearest neighbor matching in which we draw up to two neighbors per treated firm. We include a caliper to avoid distant matches which might induce bias otherwise. Tables 9 and 10 show the same descriptive statistics after the matching process. The matched sample of Dutch firms includes 141 pledgors matched to 275 similar non-pledging firms. The matched sample of Swedish firms include 126 patent pledgors matched to 248 non-pledging firms. There are no significant differences between the groups for the matched variables. Consequently, patent pledging and non-pledging firms are observably similar with respect to

firm characteristics determining their access to debt.

Table 9: Summary statistics for the matched sample of Dutch firms

	Unmatched			Matched		
	Pledgor	Control	p>|t|	Pledgor	Control	p>|t|
Total Assets	11797266.83	6196369.24	0.000	5176222.93	4569518.41	0.485
Debt	8533104.55	3753412.91	0.000	3545059.02	2986737.71	0.293
Age	18.42	21.84	0.033	16.54	16.30	0.908
Patentstock	2.71	1.06	0.000	1.81	1.48	0.116
Patentstock^2	21.07	129.29	0.002	7.47	5.88	0.579
Forward Cites	0.21	0.13	0.000	0.17	0.16	0.724
N	193	90572		147	286	

All monetary values are in Thd. Euros.

Table 10: Summary statistics for the matched sample of Swedish firms

	Unmatched			Matched		
	Pledgor	Control	p>|t|	Pledgor	Control	p>|t|
Total Assets	16989109.97	9611824.67	0.109	6077959.58	3957394.65	0.115
Debt	8763026.30	5145662.80	0.117	3355112.52	2222064.37	0.136
Age	14.55	22.01	0.000	13.45	13.01	0.787
Patentstock	2.78	1.24	0.000	2.28	1.76	0.199
Patentstock^2	28.08	33.42	0.562	17.05	14.42	0.758
Forward Cites	0.30	0.14	0.000	0.29	0.27	0.314
N	137	77381		130	257	

All monetary values are in Thd. Euros.

Tables 11 and 12 show the summary statistics for the matched sample of patent pledging firms, separated for the pre- and post-treatment period. The average debt levels increases signficiantly in the period following the colleratization of patents. However, other observable firm characteristics including equity, the number of employees, and the number of patents are higher in post-treatment periods as well. Therefore, the increase in debt levels could be partially explained by an increase in the size of firms. The following difference-in-difference analysis will include controls for firm's equity, employment, patent stock, and the number of forward citations of firms patent portfolio thus, account for potential size effects and effects driven by differences in patents value.

3.4 Estimation Results

3.4.1 Main Results

Table 13 presents the empirical results for the CDID regressions on the impact of a patent pledging on the debt level for the matched sample of Dutch firms. The first two columns show the results with and without controls for the CDID estimation. Columns 3 and 4 show the results with and without controls for the dynamic CDID estimation taking

Table 11: Summary statistics for patent-pledging Dutch firms

	Pre-pledge					Post-pledge till t=4				
	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Total Assets	216	7254.84	8958.65	15.79	46669.60	291	7273.82	11217.61	11.53	91606.00
Debt	216	4736.59	5497.57	0.18	29598.12	291	5112.48	8596.24	8.24	79489.00
Equity	216	2467.66	4225.59	-3000.48	19327.39	291	2048.49	4120.03	-2611.34	22379.90
Employees	216	41.21	50.76	1.00	239.00	291	34.41	49.46	1.00	300.00
Age	216	20.35	21.88	1.00	99.00	291	22.46	22.43	1.00	103.00
Patentstock	216	1.71	2.02	0.00	18.21	291	1.61	1.86	0.04	15.48
Forward Cites	216	0.21	0.29	0.00	2.15	291	0.22	0.30	0.00	2.15
# Patents	216	3.93	5.20	0.00	46.00	291	4.85	6.48	1.00	46.00
# Pledged patents	216	0.00	0.00	0.00	0.00	95	2.33	2.44	1.00	17.00
N	216					291				

All monetary values are in Thd. Euros.

Table 12: Summary statistics for patent-pledging Swedish firms

	Pre-pledge					Post-pledge till t=4				
	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Total Assets	240	8928.43	17324.51	17.15	126301.00	400	8961.67	21712.72	13.85	167653.00
Debt	240	4672.67	8796.55	2.93	47572.00	400	5608.56	16283.57	3.03	133773.00
Equity	240	4388.21	11976.58	-120.00	121260.00	400	3422.62	8167.96	-126.00	49729.00
Employees	240	55.98	143.48	0.00	853.00	400	44.84	115.58	0.00	774.00
Age	240	16.04	16.67	1.00	78.00	400	16.82	15.96	1.00	81.00
Patentstock	240	2.63	3.90	0.00	24.76	400	2.32	3.86	0.05	30.29
Forward Cites	240	0.38	0.40	0.00	2.19	400	0.37	0.38	0.00	2.23
# Patents	240	5.95	9.85	0.00	46.00	400	5.95	9.85	1.00	64.00
# Pledged patents	240	0.00	0.00	0.00	0.00	124	3.27	5.84	1.00	43.00
N	240					400				

All monetary values are in Thd. Euros.

pre-treatment dummies into account. The variable of interest "*post_pledge*" shows a positive sign with highly significant coefficients at the 5% level. Thus, firms significantly increase debt finance after pledging patents. In terms of magnitude, patent pledging firms increase debt by about 34%[5] relative to the counterfactual situation in which no patent would have been used as collateral.

Figure 9 graphically visualizes the estimated coefficients of the "dynamic" difference-in-difference analysis. Both coefficients of pre-treatment indicators are insignificant. Thus, we find no evidence for diverging trends between pledging firms and control groups of non-pledging firms in years prior the pledging event. Consequently, the estimated treatment effects are unlikely to be driven by firm specific trends in debt finance for pre-treatment periods. Most importantly, the graph shows a significant jump for firms' debt levels in post-treatment periods starting in the year of the pledging event. This shows that Dutch firms increase debt immediately after the patent collaterlization.

Table 14 presents the empirical results for the difference-in-difference regression concerning the impact of a patent pledging event on debt level for the matched sample of Swedish firms. The first two columns show the results with and without controls for the simple difference-in-difference estimation. Column 3 and 4 show the results with and without controls for the dynamic difference-in-difference estimation, respectively. The average treatment effects for the Swedish sample are smaller than for the Dutch sample. Patent pledging firms in Sweden increase debt by about 20%. Interestingly, post-treatment effects are only significant starting the second and third year following the pledging event. Thus, the increase in debt occurs mainly in the third year after patents have been pledged. A possible explanation for the delay might be that collateralized loans are only taken up sequentially and not in full amount immediately. This is common in, for example, loan contracts for buildings that are under construction.

[5] $100 \times \left(e^{0.29} - 1\right)$

Table 13: Difference-in-difference regression estimating the impact of patent pledging on debt level in the Netherlands

	Diff-in-Diff		Dynamic Diff-in-Diff	
Dep. Variable:	Log(Debt)	Log(Debt)	Log(Debt)	Log(Debt)
$post\_pledge$	0.23**	0.23**		
	(0.099)	(0.092)		
$pre(t2)\_pledge$			-0.069	-0.061
			(0.16)	(0.15)
$pre(t1)\_pledge$			0.023	0.011
			(0.15)	(0.15)
$post(t1)\_pledge$			0.26*	0.26**
			(0.13)	(0.13)
$post(t2)\_pledge$			0.33**	0.33**
			(0.15)	(0.15)
$post(t3)\_pledge$			0.24	0.26*
			(0.16)	(0.15)
$post(t4f)\_pledge$			0.051	0.059
			(0.17)	(0.17)
$Log(Equity)$		-0.021***		-0.019***
		(0.0043)		(0.0043)
$Log(Employees)$		0.27***		0.27***
		(0.033)		(0.033)
$Log(Patent\_Stock)$		0.18***		0.16***
		(0.049)		(0.049)
$Log(Forward\_Cites)$		0.50*		0.50*
		(0.26)		(0.26)
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
F	5.26	27.9	3.02	15.7
R-squared	0.83	0.84	0.83	0.84
N	2930	2930	2930	2930

This table presents the results for the difference-in-difference regression estimating the impact of patent pleding on firms' debt level. Regression accounts for sampling weights. Robust standard errors are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14: Difference-in-difference regression estimating the impact of patent pledging on debt level in Sweden

	Diff-in-Diff		Dynamic Diff-in-Diff	
Dep. Variable:	Log(Debt)	Log(Debt)	Log(Debt)	Log(Debt)
$post\_pledge$	0.31***	0.19***		
	(0.082)	(0.072)		
$pre(t2)\_pledge$			-0.16	0.036
			(0.16)	(0.13)
$pre(t1)\_pledge$			-0.079	-0.012
			(0.14)	(0.13)
$post(t1)\_pledge$			0.17	0.14
			(0.11)	(0.10)
$post(t2)\_pledge$			0.13	0.14
			(0.14)	(0.12)
$post(t3)\_pledge$			0.34***	0.30***
			(0.12)	(0.10)
$post(t4f)\_pledge$			0.32***	0.23**
			(0.10)	(0.089)
$Log(Equity)$		0.020**		0.019**
		(0.0092)		(0.0092)
$Log(Employees)$		0.60***		0.59***
		(0.034)		(0.035)
$Log(Patent\_Stock)$		0.36***		0.41***
		(0.047)		(0.053)
$Log(Forward\_Cites)$		-0.32*		-0.38**
		(0.17)		(0.18)
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
F	14.6	106.8	4.15	50.5
R-squared	0.86	0.89	0.86	0.89
N	4160	4160	4160	4160

This table presents the results for the difference-in-difference regression estimating the impact of patent pleding on firms' debt level. Regression accounts for sampling weights. Robust standard errors are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

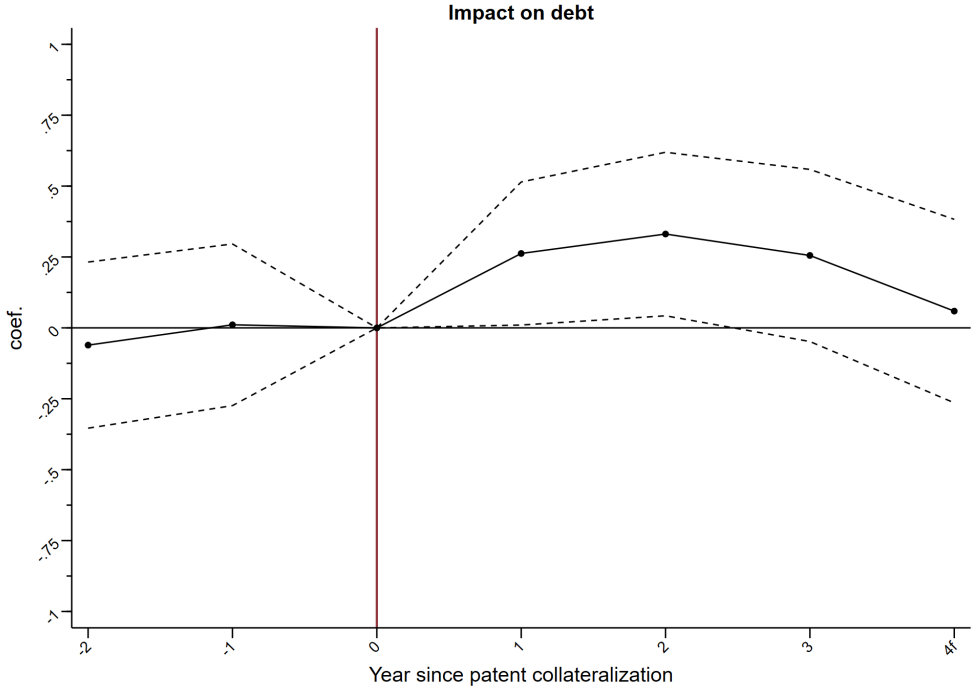


Figure 9: Coefficient plots for the dynamic difference-in-difference estimation using the Dutch sample

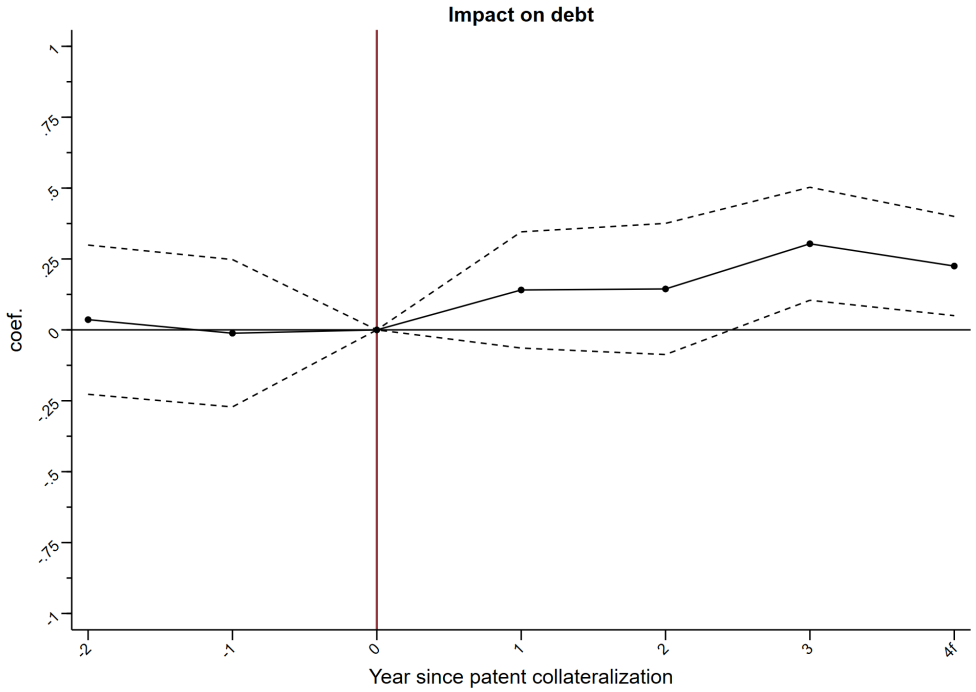


Figure 10: Coefficient plots for the dynamic difference-in-difference estimation using the Swedish sample

Control variables for employment and firms patent stock show a positive coefficient in

both samples. This is in line with the financial literature that defines firm size as the main determinant of firms' access to debt (Hadlock & Pierce 2010). Furthermore, the positive coefficient for the patent stock confirms (Hottenrott et al. 2016) findings on the signaling value of patents to external investors. Our results show that a one percent increase in firms' patent stock is associated with a 17% increase in the debt levels of Dutch firms and 37% increase in the debt levels of Swedish firms. Thus, Dutch firms can increase their debt by pledging patents more than their Swedish counterparts. However, the signaling value of patents seems to be more pronounced in Sweden. Last, the coefficients for the number of forward citations on the portfolio level show different signs for the Dutch and Swedish samples. This is likely due to the strong correlation with the patent stock variable.[6]

3.4.2 Placebo Test

A key assumption for the difference-in-difference analysis is the common trend assumption. In our setting, this means that in the absence of a patent pledging event, the debt levels of treatment and controls groups should have followed the same trend. To further prove the validity of our empirical design, we performe a placebo test for randomly assigned "fake" pledging events in the pre-treatment period of patent pledging Dutch and Swedish firms.[7] Afterwards the assignment of fake pledging events, we estimate the identical difference-in-difference analysis applied in our main analysis. The idea of this placebo test is that the fake pledging event should not alter firms' debt level if the firms follow the same trend in debt finance.

Tables 16 and 18 show the results of the difference-in-difference analysis using "fake" patent pledging events in pre-treatment periods for Sweden and the Netherlands receptively. In both samples the treatment indicator "*post_pledge*" show a small and insignificant coefficient. Hence, fake pledging events in pre-treatment periods do not alter firms' debt level. This further supports the assumption that firms in our main analysis follow the same trend in debt finance in years prior the patent pledging event, and that our actual treatment effects estimations are indeed causal.

[6]Unreported results where we include controls individually show a postive sign for the number of forward citations on the portfolio level in both samples. This is in line with the expectation that patents with higher underlying technological quality (value) are more likely to be pledged.

[7]"Fake" pledge events have been assigned for each patent pledging firm at a random year prior the actual pledging event.

Table 15: Summary statistics for the Dutch placebo sample

	Patent pledging firms					Non-pledging firms				
	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Total Assets	2124	18462.64	61351.94	1.72	855793.00	115603	14579.25	65996.05	1.39	976000.00
Debt	2048	9266.63	17142.16	0.16	142032.00	110190	4714.08	14114.39	0.10	160524.00
Equity	2043	6019.16	21469.21	-4080.92	385525.86	114255	5405.65	24919.37	-4088.00	406400.65
Employees	1372	128.31	379.16	1.00	5906.00	69976	90.15	437.53	1.00	40045.00
Age	2124	21.36	22.22	0.00	116.00	115576	21.81	22.99	0.00	314.00
Patentstock	2124	4.42	43.85	0.00	1121.30	115603	1.22	13.17	0.00	1035.30
Forward Cites	2124	0.27	0.35	0.00	2.39	115603	0.18	0.42	0.00	13.37
N	2124					115603				

The sample includes 9064 non-pledging firms and 191 patent pledging firms with randomly assigned pledging events observed between 1994 and 2018. True pledging events have been replace by fake pledging events in periods prior the actual patent pledging event. Periods after the patent pledging events of patent pledging firms have been dropped. All monetary values are in Thd. Euros.

Table 16: Difference-in-difference regression estimating the impact of a fake pledging events in pre-treatment periods on debt level in the Netherlands

	Diff-in-Diff	
Dep. Variable:	Log(Debt)	Log(Debt)
post_pledge	-0.072	-0.10
	(0.087)	(0.085)
$Log(Equity)$		-0.015***
		(0.0013)
$Log(Employees)$		0.25***
		(0.0081)
$Log(Patent\_Stock)$		0.26***
		(0.015)
$Log(Forward\_Cites)$		0.29***
		(0.064)
Year FE	YES	YES
Firm FE	YES	YES
F	0.69	313.9
R-squared	0.86	0.87
N	56148	56148

This table presents the results for the difference-in-difference regression estimating the impact of fake patent pledging events on firms' debt level. egression accounts for sampling weights. Robust standard errors are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 17: Summary statistics for the Swedish placebo sample

	Patent pledging firms					Non-pledging firms				
	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Total Assets	441	39925.12	117773.81	8.30	821324.00	98866	13064.17	59438.90	5.18	949975.72
Debt	410	10432.37	30002.43	1.60	203694.00	88952	5071.65	17566.38	0.87	204978.81
Equity	425	12868.55	36311.79	-120.00	364397.19	97825	5220.08	22824.25	-129.52	372612.00
Employees	413	179.35	589.17	0.00	4929.00	91193	63.60	330.17	0.00	40567.00
Age	441	15.44	18.23	0.00	100.00	98866	21.58	19.36	0.00	120.00
Patentstock	441	4.02	11.31	0.00	125.27	98866	1.31	6.83	0.00	410.56
Forward Cites	441	0.36	0.37	0.00	2.19	98866	0.19	0.38	0.00	14.31
N	441					98866				

The sample 7500 non-pledging firms and 123 patent pledging firms with randomly assigned pledging events observed between 1997 and 2018. True pledging events have been replace by fake pledging events in periods prior the actual patent pledging event. Periods after the patent pledging events of patent pledging firms have been dropped. All monetary values are in Thd. Euros.

Table 18: Difference-in-difference regression estimating the impact of a fake pledging events in pre-treatment periods on debt level in Sweden

	Diff-in-Diff	
Dep. Variable:	Log(Debt)	Log(Debt)
post_pledge	-0.15*	-0.11
	(0.087)	(0.076)
Log(Equity)		0.011***
		(0.0023)
Log(Employees)		0.65***
		(0.011)
Log(Patent_Stock)		0.22***
		(0.012)
Log(Forward_Cites)		0.16***
		(0.047)
Year FE	YES	YES
Firm FE	YES	YES
F	2.84	1031.9
R-squared	0.88	0.91
N	75492	75492

This table presents the results for the difference-in-difference regression estimating the impact of fake patent pledging events on firms' debt level. egression accounts for sampling weights. Robust standard errors are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.5 Conclusion

It is well known that many innovative companies are financially constrained. The literature shows that patents can mitigate such financial frictions through their signaling value by reducing information asymmetries between borrowers and lenders. However, patents

can also serve as loan collateral and thereby improve firms' access to debt. This collateral channel has attracted surprisingly little attention in the existing literature.

In this paper, we estimate the impact of patent-pledging on firms' debt level using a quasi-experimental set-up by implemting conditional difference-in-difference regressions. Thus, we provide causal evidence for the increase in firms' debt capacity through the pledging of patents. We show for a sample of Dutch and Swedish patent filing firms that the patent pledging event causes an increase in the level of debt by about 34% for Dutch pawners and about 20% for Swedish pawners.

It is possible to translate our marginal effects into monetary values by multiplying the effect size with the firms' debt level prior to the pledging event. This implies that Dutch (Swedish) firms were able ro raise, on average, 1.38 (1.24) million additional euros debt by offering patents as loan collateral. However, our descriptive statistics show that only a few patent-filing firms pledged their patents compared to the number of patent-owning firms. This implies that innovators in Sweden and the Netherlands currently do not exhaust all financing opportunities. Specifically, non-pledging Dutch (Swedish) firms could raise addtional 5.1 billion euro (13.4 billion euro) external funding in total by offering their patents as loan collateral, all else constant.

We can also revisit prior findings on the positive signaling value of patents. Our results show that firms patent stock is associated with a 17% increase in the debt levels of Dutch firms and 37% increase in the debt levels of Swedish firms. In monetary terms, this means that the signaling value of pledged patents can explain an average increase in debt of 594 thousand euro for Dutch firms and an average increase in debt of 1.8 million euro for Swedish firms.[8] This suggests that the collateral value of patents exceeds their signaling value for firms in the Netherlands but not for firms in Sweden.

Finally, our results can also seen as contribution to the literature on patent valuation that, for example, assesses marginal effects of (quality–weighted) patent stocks on firms' market value. We offer a new method to assess minimum values of patent portfolios as our estimated treatment effects may reflect the value of patents to the extent that a lender commits additional financial resources for patents being used as collateral.

There are some important limitations to our results. First, companies do not pledge patents at random. Since we were unable to find a suitable instrument for the pledging event[9], we applied a CDiD regression for a matched sample to mitigate selection effects.

[8]The calculation of the signaling value is based on the average patent stock prior to the pledging event which is equal to 1.69 (2.91) in the Netherlands (Sweden). Adding the average number of pledged patents (2.26 in the Netherlands and 3.53 in Sweden) leads to an increase in the patent stock by 84.9% (79.44%) in the Netherlands (Sweden). Consequently, the increase in the patent stock by the number of pledged patents corresponds to an increase in debt by about 14% (29%) for Dutch (Swedish) firms.

[9]We have tried to use variation in real estate prices at the location of the companies, the distance between firms and their national patent office, regional variation in the share of relationship banks to total banks and weather shocks at the firm's location. However, neither of the purposed instruments significantly explained patent pledging.

However, the matching of a similar control group of non-pleding firms is based on observable firm characteristics. Thus, we cannot exclude the possibility that unobserved firm characteristics drive both firms' access to debt and the decision to pledge patents. Second, our empirical analysis is based on Dutch and Swedish firms which limits the generalizability of our results to countries with a similar economy and legal framework.

References

Abadie, A. & Spiess, J. (2021), 'Robust post-matching inference', *Journal of the American Statistical Association* pp. 1–13.

Aghion, P. & Howitt, P. (1990), A model of growth through creative destruction, Technical report, National Bureau of Economic Research.

Almeida, H. & Campello, M. (2007), 'Financial constraints, asset tangibility, and corporate investment', *The Review of Financial Studies* **20**(5), 1429–1460.

Arora, A. & Gambardella, A. (2010), The market for technology, *in* 'Handbook of the Economics of Innovation', Vol. 1, Elsevier, pp. 641–678.

Arrow, K. J. (1972), 'Economic Welfare and the Allocation of Resources for Invention', *Readings in Industrial Economics* pp. 219–236.

Beck, T. et al. (2007), Financing constraints of smes in developing countries: Evidence, determinants and solutions, *in* 'KDI 36th Anniversary International Conference', pp. 26–27.

Benmelech, E. (2008), 'Asset salability and debt maturity: Evidence from nineteenth-century american railroads', *The Review of Financial Studies* **22**(4), 1545–1584.

Bester, H. (1985), 'Screening vs. rationing in credit markets with imperfect information', *The American economic review* **75**(4), 850–855.

Bloom, N. & Van Reenen, J. (2002), 'Patents, real options and firm performance', *The Economic Journal* **112**(478), C97–C116.

Brown, J. R., Fazzari, S. M. & Petersen, B. C. (2009), 'Financing innovation and growth: Cash flow, external equity, and the 1990s r&d boom', *The Journal of Finance* **64**(1), 151–185.

Cuneo, P. & Mairesse, J. (1983), 'Productivity and r&d at the firm level in french manufacturing'.

Czarnitzki, D., Ebersberger, B. & Fier, A. (2007), 'The relationship between r&d collaboration, subsidies and r&d performance: empirical evidence from finland and germany', *Journal of applied econometrics* **22**(7), 1347–1366.

Czarnitzki, D., Hall, B. H. & Oriani, R. (2006), 'The market valuation of knowledge assets in us and european firms'.

Czarnitzki, D. & Hottenrott, H. (2011), 'R&d investment and financing constraints of small and medium-sized firms', *Small Business Economics* **36**(1), 65–83.

Czarnitzki, D. & Hottenrott, H. (2017), 'Inter-organizational collaboration and financing constraints for r&d', *Economics Letters* **161**, 15–18.

Ekman, P., Hadjikhani, A. I., Pajuvirta, A. & Thilenius, P. (2014), 'Tit for tat and big steps: The case of swedish banks' internationalization 1961–2010', *International Business Review* **23**(6), 1049–1063.

Fazzari, S. M. & Petersen, B. C. (1993), 'Working capital and fixed investment: new evidence on financing constraints', *The RAND Journal of Economics* pp. 328–342.

Fischer, T. & Ringler, P. (2014), 'What patents are used as collateral?—an empirical analysis of patent reassignment data', *Journal of Business Venturing* **29**(5), 633–650.

Gambardella, A., Harhoff, D. & Verspagen, B. (2008), 'The value of European patents', *European Management Review* **5**(2), 69–84.

Goldfinger, C. (1997), 'Intangible economy and its implications for statistics and statisticians', *International Statistical Review* **65**(2), 191–220.

Granstrand, O. & Holgersson, M. (2012), 'The anatomy of rise and fall of patenting and propensity to patent: the case of sweden', *Granstrand, O. and 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* **5**(2), 169–198.

Grupp, H., Münt, G. & Schmoch, U. (1996), 'Assessing different types of patent data for describing high-technology export performance', *Innovation, patents and technological strategies* pp. 271–287.

Hadlock, C. J. & Pierce, J. R. (2010), 'New evidence on measuring financial constraints: Moving beyond the kz index', *The Review of Financial Studies* **23**(5), 1909–1940.

Hall, B. H., Jaffe, A. B. & Trajtenberg, M. (2001), The nber patent citation data file: Lessons, insights and methodological tools, Technical report, National Bureau of Economic Research.

Hall, B. H., Jaffe, A. & Trajtenberg, M. (2005), 'Market value and patent citations', *RAND Journal of economics* pp. 16–38.

Hall, B. H. & Lerner, J. (2010), The financing of r&d and innovation, *in* 'Handbook of the Economics of Innovation', Vol. 1, Elsevier, pp. 609–639.

Hall, B. H., Moncada-Paternò-Castello, P., Montresor, S. & Vezzani, A. (2016), 'Financing constraints, r&d investments and innovative performances: new empirical evidence at the firm level for europe'.

Harhoff, D. (2000), Are there financing constraints for r&d and investment in german manufacturing firms?, *in* 'The economics and econometrics of innovation', Springer, pp. 399–434.

Harhoff, D., Scherer, F. M. & Vopel, K. (2003), 'Citations, family size, opposition and the value of patent rights', *Research policy* **32**(8), 1343–1363.

Hochberg, Y. V., Serrano, C. J. & Ziedonis, R. H. (2018), 'Patent collateral, investor commitment, and the market for venture lending', *Journal of Financial Economics* **130**(1), 74–94.

Hottenrott, H., Hall, B. H. & Czarnitzki, D. (2016), 'Patents as quality signals? the implications for financing constraints on r&d', *Economics of innovation and new technology* **25**(3), 197–217.

Ivashina, V. & Scharfstein, D. (2010), 'Bank lending during the financial crisis of 2008', *Journal of Financial economics* **97**(3), 319–338.

Kerr, W. R. & Nanda, R. (2015), 'Financing innovation', *Annual Review of Financial Economics* **7**, 445–462.

Mann, W. (2018), 'Creditor rights and innovation: Evidence from patent collateral', *Journal of Financial Economics* **130**(1), 25–47.

Ministry of Justice Stockholm (1967*a*), 'Patents act (1967:837)'. Art. 95., [Last Accessed: August 15th 2017].
URL: *https://www.prv.se/globalassets/dokument/patent/informationsmaterial/the-patents-act---unofficial-translation.pdf*

Ministry of Justice Stockholm (1967*b*), 'Patents act (1967:837)'. Art. 95., [Last Accessed: June 15th 2018].
URL: *https://www.prv.se/globalassets/dokument/patent/informationsmaterial/the-patents-act---unofficial-translation.pdf*

Modigliani, F. & Miller, M. H. (1958), 'The cost of capital, corporation finance and the theory of investment', *The American economic review* **48**(3), 261–297.

Myers, S. C. & Majluf, N. S. (1984), 'Corporate financing and investment decisions when firms have information that investors do not have', *Journal of financial economics* **13**(2), 187–221.

Nelson, R. R. (1959), 'The simple economics of basic scientific research', *Journal of political economy* **67**(3), 297–306.

OECD (2009), *OECD Patent Statistics Manual*.
URL: *https://www.oecd-ilibrary.org/content/publication/9789264056442-en*

Patent Act 1995 (n.d.).
URL: *https://english.rvo.nl/topics/innovation/patents-other-ip-rights-topic/patent-law/patent-act-1995*

Revest, V. & Sapio, A. (2012), 'Financing technology-based small firms in europe: what do we know?', *Small Business Economics* **39**(1), 179–205.

Romer, P. M. (1990), 'Endogenous technological change', *Journal of political Economy* **98**(5, Part 2), S71–S102.

Scherer, F. M. (1965), 'Firm size, market structure, opportunity, and the output of patented inventions', *The American economic review* **55**(5), 1097–1125.

Shleifer, A. & Vishny, R. W. (1992), 'Liquidation values and debt capacity: A market equilibrium approach', *The Journal of Finance* **47**(4), 1343–1366.

Steijvers, T. & Voordeckers, W. (2009), 'Collateral and credit rationing: a review of recent empirical studies as a guide for future research', *Journal of Economic Surveys* **23**(5), 924–946.

Stiglitz, J. E. & Weiss, A. (1981), 'Credit rationing in markets with imperfect information', *The American economic review* **71**(3), 393–410.

The Minister of Justice Den Haag (1995), 'the dutch patents act'. Art. 67., [Last Accessed: March 25th 2022].
URL: *https://english.rvo.nl/sites/default/files/2013/12/ROW95_ENG_niet_officiele_vertaling_0.pdf*

Trajtenberg, M. (1990), 'A penny for your quotes: patent citations and the value of innovations', *The Rand journal of economics* pp. 172–187.

Williamson, O. E. (1988), 'Corporate finance and corporate governance', *The journal of finance* **43**(3), 567–591.