Effect of Technical Competition on Patent Collateralization for Debt Financing

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ABSTRACT
I estimate the effect of technical competition on a company's choice of patents to be used as collateral for debt financing. I find that patents in more competitive fields are more likely to be used as collateral. Previous literature has shown that patents in competitive technical fields are less valuable to companies. The results of this paper show that while these patents are relatively ineffective at protecting companies from competitors, collateralization provides another opportunity for companies to realize the financial value of patent ownership. The possibility to use patents as collateral incentivizes companies to continue publishing their innovations in these competitive technical fields. I perform this analysis on a novel dataset created by joining company characteristics from Crunchbase with patent characteristics from the United States Patent and Trademark Office.

CCS Concepts
•Social and professional topics → Computing / technology policy → Intellectual property → Patents

•Human-centered computing → Collaborative and social computing → Empirical studies in collaborative and social computing

Keywords
Competition; debt-financing, technology, intellectual-property.

1. INTRODUCTION
Patenting requires companies to publish their innovations in exchange for the rights to exclude competitors from using the innovations. The protection from competition conferred by patents[1] generates funds for company's continuous research and development in the technical field [1]. However, intense competition in a technical field can weaken the protection from patents and cause a higher frequency of patent disputes, reducing company's incentive to patent their technologies. I look at the use of patents as collateral in debt financing process and find that patents in more competitive technical fields are more likely to be used as collateral. Collateralization of intangible assets for debt finance creates an incentive for companies to continue publishing technologies in a competitive technical field.

I am interested in the effect of technical competition in the field the patents are in rather than market competition the patent owner faces. In the rest of this paper, "competition" refers to the technical competition. The literature has shown the negative impact technical competition has on the propensity to patent. Lanjouw [2] looks at competition within the technical field[2] patents are in and finds that patents with more technical depth and larger application area (also called a wider scope[3]) are more likely to be involved in patent infringement litigations. Graham et al. [3] find that patents are less necessary when they are in a technical field that is experiencing faster growth and heavier competitions because these patents cannot effectively protect firms' competitive positions. Moreover, the costs associated with applying and owning a patent in a more competitive technical field can make patenting less appealing. The lower incentive to publish innovations, in turn, increases informational asymmetry between firms and investors [4], and worsens the overall technological progress because new inventions are not able to build on existing ones when they are developed and used in secrecy [1].

The results of this paper show that technical competition can also drive the use of patents as collateral for debt financing and therefore creates additional motivation for companies to patent their inventions, despite the costs associated with patent ownership. In debt financing, companies take on debt and pay back the amount in a predetermined time in the future. Financial institutions that act as lenders often require collateral so that they can salvage the collateral to recover some of the loss in case of default. The use of patents as collateral in debt financing is prevalent among companies, and intangible assets like patents are considered as important as tangible assets when used as collateral [5]. When collateralizing patents, the creditor (company) temporarily assigns the patent to the lender in exchange for the loan. If the loan is not repaid in time, the lender will get the full ownership of the collateralized patents. Collateralization creates a means to obtain finance needed for company's operation and future R&D. I examine the factors affecting company's choice of patents as collateral and find that technical competition in a patent's technical field positively contributes to the company's decision to collateralize it. This result shows that collateralization brings financial incentive for companies to patent their innovations,

[1] I use "patents" and "intellectual properties" interchangeably.

[2] Lanjouw [2] followed International Patent Classification (IPC) code in their analysis. I use Cooperative Patent Classification (CPC).

[3] A patent that has a large scope has a wide range of applications to different fields. The number of applications is usually measured by the number of claim statements submitted by a patent.

countering, to some extent, the additional financial burden from the more intense competition in a technical field.

I identified one previous study that examines factors affecting company's choice of patents as collateral. By looking at security agreements from 2000 to 2006, Fischer and Ringler [6] focus their analysis on the effect of technology and scope characteristics of the patents that are used as collateral. They find support for technology-related characteristics in the collateralization process but not for scope related characteristics. In this analysis, I use a larger patent-level dataset and include company characteristics and industry fixed effects. The results provide empirical evidence supporting the idea that competition in the technical field, in addition to technological depth, impacts a company's choice of patents as collateral. The empirical results prove that the possibility to use patents as collateral to obtain debt financing provides another motivation for companies to publish their innovations despite intense competition, contributing to the growth of knowledge in an economy.

2. Data

To understand collateralization patent choices, I start by obtaining the company-level data from Crunchbase[4]. I then use the company data to look for their patents and the patents' collateralization history using natural language processing. Finally, I join company-level data to patent-level data using fuzzy matching[5] on company names. The result dataset used for the analysis is cross-sectional.

2.1 Company-Level Data

The company-level data come from Crunchbase, a company that maintains datasets on companies, investors, investment, acquisitions, et cetera. The data in Crunchbase are provided by company employees and investors. Companies and individuals that are listed on Crunchbase have the incentive to keep their profiles accurate and up to date because the information is shared with potential investors and consumers. The Crunchbase dataset is used because of its extensive information on privately-owned companies. The company-level data is a snapshot of all company information on Crunchbase requested on February 26, 2018.

The original dataset from Crunchbase has information on 647,194 organizations around the world. I focus my analysis on companies[5] that are currently operating [6] in the U.S. I further make the distinction between private and public companies. Only companies that have at least one patent collateralization record are included to ensure that companies in the analysis are aware of the possibility of using intellectual property for debt financing. The result company-level dataset has information on 4072 companies.

See Table 1 and 2 for a list of company-level variables that are included in this analysis. I also include the industry information from Crunchbase dataset to control for industry fixed effects.

Table 1: Company-Level Variable Definitions

Variable	Definition
Assignee Total Number of Inventors	Total number of inventors working for a given assignee.
Funding Rounds	Number of funding rounds a company has gone through.
Funding Total USD	Total amount of funding a company has received.
Days since Founded	Number of days since the company was founded.
Days since Last Funding	Number of days elapsed since the last funding round.
Status	Whether a company is a public or private company.
Employee Count	Total number of employees in an organization.
Invest	Whether the company participate in investment activities in other firms.

Table 2: Company-Level Summary Statistics

Variable	Obs.	Mean	S.D.	Min	Max
Assignee Total Number of Inventors	4072	25.20	191.21	1.00	5574.92
Funding Rounds	4072	3.68	2.85	1.00	26.00
Funding Total USD	4072	16.09	2.13	7.70	24.13
Days since Founded	4072	8.27	0.63	5.29	11.13
Days since Last Funding	4072	6.75	0.95	3.18	9.46

2.2 Patent-Level Data

Using the information on company names obtained from Crunchbase, I then use PatentsView, a prototype patent data service developed with the support from the United States Patent and Trademark Office (USPTO), to query U.S. patents associated with companies and find a total of 124168 patents. USPTO patent database has a comprehensive record on all patents associated with U.S. companies because all U.S. patents are required to be filed with USPTO. PatentsView provides USPTO patent data in a format that is easily accessible through scripting languages[7]. Table 3 and 4 shows the list of variables used in the analysis and their definitions.

[4] See http://Crunchbase.com/

[5] This analysis on chooses organizations that are identified as an entity that acts as a "company" or a "company" and "investor" by Crunchbase dataset. It does not include entities that act as an academic institution, a group, or solely an investor.

[6] This analysis excluded companies that have been acquired, closed, or have an unknown status.

[7] The data is accessed on March 9, 2018 using PatentsView API. The API has an upper limit of 10,000 patents per company. To ensure the integrity of this analysis, I dropped the companies that have more than 10,000 patents.

Table 3: Patent-Level Variable Definitions

Variable	Definition
Patent Date	Number of days elapsed between February 26, 2018, and the date the given patent was granted. All values are positive.
Number of Claims	Number of claim statements on the given patent.
Number of Citations	Number of patents and patent applications around the world cited by the given patent. This is the sum of citations of US patents, foreign patents, and US applications.
Patent Processing Time	Number of days elapsed from filing application date to grant date for the patent.
Number of Assignees	Total number of unique assignees on patents within a CPC subsection. Cooperative Patent Classification (CPC) is a patent classification system that categorizes patents by their technical features. Assignee refers to the owner of a patent.

Table 4: Patent-Level Summary Statistics

Variable	Obs.	Mean	S.D.	Min	Max
Patent Date	124168	3942.3	3797.6	110	15412
Number of Claims (Scope)	124168	19.2	13.2	0	499
Number of Citations (Technology)	124168	56.9	130	0	3255
Patent Processing Time	124168	1057.9	617.7	0	12103
Number of Assignees (Competition)	124168	33069	19968.5	609	60213

2.3 Collateralization History

The patent data obtained from USPTO do not contain information on the collateralization and redemption status. I start by accessing[8] the patent reassignment history through USPTO patent reassignment database. The reassignment history records the reassignment of the patent ownership to banks when a patent is collateralized and the redemption of the patents when the debt is paid off. While reporting reassignment and redemption to USPTO is not required for the parties involved in the transactions, recording them on USPTO acts as an enforceable agreement between the lenders and creditors. Therefore, USPTO provides reliable collateralization and redemption records on patents in this dataset. Among the 124168 patents collected, 7162 patents have been used as collateral at the time of analysis, and 3482 have been redeemed after collateralization.

[8] The reassignment data is accessed on March 9, 2018. The data is obtained through Python web scraping on http://legacy-assignments.uspto.gov/assignments/.

Table 5: Collateralization Result Summary Statistics

Variable	Levels	Obs.	Proportion
Collateralized	False	117006	94.2%
	True	7162	5.8%
	All	124168	100%
Redeemed	False	3680	51.4%
	True	3482	48.6%
	All	7162	100%

3. Model

I am interested in the effect of competition in patent's technical field on company's decision to collateralize patents. The hypothesis is that intense competition gives companies more incentive to collateralize these patents for debt financing to better realize their value. Previous literature has shown that patents in more competitive fields tend to lose their ability to protect company's competitive position at a faster rate and that they bring higher possibility of patent infringement lawsuits. While these patents are not effective as a set of exclusion rights, they can be used as collateral to help the company obtain the finance needed for future research activities, therefore improving company's willingness to patent despite heavy competition. To estimate the impact of technical competition on the collateralization decisions of patents, I control the effect of patent characteristics, company characteristics, and industry fixed effects. I also take into account the two particular patent characteristics, technology and scope, that are found to affect the collateralization decisions in previous literature. The regression setup is shown below. $V_{competition}$, $V_{technology}$, and V_{scope} are each one variable. $V_{patentControls}$, $V_{firmControls}$, and $V_{industryFE}$ are each a list of variables.

$$Collateralized = \beta_1 V_{competition} + \beta_2 V_{technology} + \beta_3 V_{scope} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \beta_6 V_{industryFE} + \varepsilon$$

I measure "competition" in the technical field by the total number of patent owners in the field, "technology" by the number of backward citations a given patent makes, and "scope" by the number of claim statements the patent has submitted. The patent controls include patent's application date and processing time. The firm controls include the set of firm characteristics variables listed in Table 1 and nominal variables on whether a firm is a public company, the number of employees in intervals, and whether the company is an investor or not. The industry fixed effects are included as industry dummy. In the rest of this section, I will discuss the importance of each factor, how they are measured, their expected contribution, followed by an overview of the estimation strategy.

3.1 Competition

I am most interested in the effect of technical competition on company's decision to collateralize a given patent. Given that more intense competition in a technical field can deter companies from applying for patents in this field, I am interested in learning whether more intense competition can also encourage the collateralization of patents that are in these fields, therefore, creating incentive for companies to continue patenting.

I measure competition by the total number of assignees in a particular technical field. Each patent is classified into a technical field defined by Cooperative Patent Classification (CPC), a patent classification system developed by the European Patent Office and the United States Patent and Trademark Office. CPC categorizes patents by their technical features. Assignee refers to an owner of a patent. A patent is first issued to the members of an organization who directly developed the patent, the patent is then reassigned to the company. Therefore, the number of assignees in a CPC field is a measure of the number of companies that own patents in a particular technical field. A larger number of assignees means that the technologies in a particular field is spread across a larger number of organizations and, therefore, reflects a higher level of competition.

I expect the number of assignees in a technical field to positively contribute to the collateralization decision. More competitive a technical field is, the less likely that companies will find their patents effective because the faster growth of technology makes the patent quickly become outdated and higher risk of patent litigations brings additional burden to patent ownership. Therefore, patents in a competitive field should be more likely to be used as collateral in the debt financing process.

3.2 Technology and Scope

Technology is a measure of the technological relevancy a patent has to the technical field it is in. The more relevant a patent is, the more direct contribution it can make to the field it is in. In the scope of this paper, technology is measured by the number of backward citations a patent has. Number of backward citations is a measure of the number of patents and applications a given patent cited at the time of its application. The larger the backward citation, the more relevant the patent is to the technical field it is in.

The scope is a measure of the number of applications a patent has. A patent with a wider application field has a wider scope. I measure scope by the number of claim statements a given patent has submitted at the time of application. Claim statements are used to define the subject-matters that the patent is intended to protect. The number of claim statements defines the number of subject-matters a patent protects and can, therefore, be used as a measure of the number of applications a patent has.

Fischer and Ringler [6] have shown in their research on factors affecting collateralization decisions that the technology characteristic of a patent influences company's collateralization decision. Although scope characteristic is found to have no significant effect, I include it to control for the variation of the effect of scope across industries.

I expect the technology and scope characteristics to negatively contribute to the collateralization decisions because a patent with wide application fields and great technological depth should be more valuable to a firm. Therefore, firms should have a lower incentive to risk the forfeiture of these patents in case of default.

3.3 Controls

The decision to collateralize patents are also influenced by a company's need for finance, administrative process of obtaining patents, and many other factors. Therefore, I control for patent and company characteristics, and focus on the effect competition in the technical field has on the collateralization decisions. Furthermore, I control for industry fixed effects through industry dummies because companies have different operating and financing behaviors across industries.

3.4 Estimation Strategy

I first run a logistic regression on the entire dataset to test the hypothesis that technical competition a patent faces directly impact a company's collateralization decisions on that patent. I then verify the result obtained using the same covariates on redemption results as the new dependent variable. Finally, I relax the assumption that variables affect all industries consistently and see if the findings hold in industry-level regressions.

In the regressions, I examine the impact of each variable using the change in McFadden's R-squared in addition to coefficients to account for the differences in the scales of variables.

4. Results

4.1 Fixed-Effect Models on Collateralization

I start with a logistic regression that includes patent characteristics, firm characteristics, and industry fixed effects. I find that more intense competition in the technical field and wider scope are associated with a higher likelihood of collateralization; higher technological contribution is associated with a lower likelihood of collateralization. The effect of competition in the technical field is consistent with the earlier hypothesis that patents in more competitive technical fields are more likely to be used as collateral. The regression results are in Table 6.

I am interested in the extent to which technical competition affects company's decision to collateralize patents, but the coefficients do not allow direct comparison of effects because of the differences in scale across variables[9]. Therefore, I compare the impact of each factor on collateralization decisions in Column (2) to (4) by taking the factor out of the baseline regression in Column (1) and examine the changes in McFadden's R^2 from that in Column (1). The following regressions are used to examine the change in McFadden's R^2 after removing key factors.

Column (1), Baseline Regression:

$$\text{Collateralized} = \beta_1 V_{competition} + \beta_2 V_{technology} + \beta_3 V_{scope} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \beta_6 V_{industryFE} + \varepsilon$$

Column (2), Remove $V_{competition}$:

$$\text{Collateralized} = \beta_2 V_{technology} + \beta_3 V_{scope} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \beta_6 V_{industryFE} + \varepsilon$$

Column (3), Remove $V_{technology}$:

$$\text{Collateralized} = \beta_1 V_{competition} + \beta_3 V_{scope} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \beta_6 V_{industryFE} + \varepsilon$$

[9] "Scope" is measured by the number of claim statements made by the patent at the time of issuance, "Technology" is measured by the number of backward citations a patent receives, and "Competition" is measured by the number of entities that own patents in a particular CPC subsection. A change in the number of assignees is more significant than a change in number of backward citations or claim statements

Column (4), Remove V_{scope}:

$$Collateralized = \beta_1 V_{competition} + \beta_2 V_{technology} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \beta_6 V_{industryFE} + \varepsilon$$

I find that removing the competition and technology measure have the largest impacts on covariates' explanatory power. Removing technology measure reduces the McFadden's R^2 by 0.00139 and removing the competition measure reduces the performance by 0.00165. The effect of scope is much smaller in comparison. Fixed effect regressions show that market competition plays a similarly significant role in the patent collateralization decisions as the technological value of the patent. Consistent with previous literature, a patent with larger technological contribution is less likely to be used as collateral. However, between two patents with similar technological contributions, the one in a more competitive technical field is more likely to be used as collateral to attain debt finance.

Table 6: Logistic Regression Estimates of Factors Affecting Collateralization Decisions[10]

	Dependent Variable			
	Collateralized			
	(1)	(2)	(3)	(4)
Scope	0.004***	0.004***	0.003***	
	(0.001)	(0.001)	(0.001)	
Technology	−0.001***	−0.001***		−0.001***
	(0.0002)	(0.0002)		(0.0002)
Ln(Competition)	0.192***		0.191***	0.195***
	(0.021)		(0.021)	(0.021)
McFadden's R^2	0.2822	0.2806	0.2808	0.2819
Change in R^2	0	−0.00165	−0.00139	−0.00027
Observations	124168	124168	124168	124168
Log Likelihood	-19655	-19700	-19693	-19663
Akaike Inf. Crit.	39439	39527	39513	39451

4.2 Robustness Check Using Redemption History

After collateralizing a patent for debt financing, companies need to decide whether to redeem the collateralized patents. The redemption records provide the opportunity for a natural robustness test for factors impacting collateralization decisions because company's redemption decisions should reflect similar consideration for a given patent. During collateralization, companies choose patents in technologically competitive fields for collateralization, which runs the risk of forfeiting the patents in case of default. Regressions on the redemption results further validate the competition's effect on company's choice of patents as collateral. The baseline regression formula used for robustness check is listed below.

$$Redeemed = \beta_1 V_{competition} + \beta_2 V_{technology} + \beta_3 V_{scope} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \beta_6 V_{industryFE} + \varepsilon$$

Market competition has a slightly larger impact than technological characteristics on company's decisions to collateralize patents. Similarly, during redemption, competition (Column (2)) plays a more significant role than technology (Column (3)) as shown by the larger decrease in McFadden's R^2 in Table 7. A negative coefficient on "competition" is consistent with the results obtained in the regressions on collateralization decisions — the more intense the competition is in a technical field, the more likely companies will collateralize the patents in that field. The negative coefficient here means that the more intense the competition, the less likely will a company pay off the loan and redeem the patent. This result again shows that companies value patents in a more competitive technical field as means to obtain debt finance.

Table 7: Logistic Regression Estimates of Factors Affecting Redemption Decisions

	Dependent Variable			
	Redeemed			
	(1)	(2)	(3)	(4)
Scope	-0.001	-0.001	-0.001	
	(0.003)	(0.003)	(0.003)	
Technology	-0.003	-0.003		-0.003
	(0.005)	(0.005)		(0.005)
Ln(Competition)	-0.268***		-0.268***	-0.268***
	(0.063)		(0.063)	(0.063)
McFadden's R^2	0.5279	0.5260	0.5278	0.5279
Change in R^2	0	−0.00182	−5e − 05	0.0
Observations	7162	7162	7162	7162
Log Likelihood	-2343	-2352	-2343	-2343
Akaike Inf. Crit.	4809	4825	4808	4807

4.3 Industry-level Regressions

Fixed effect regressions make the assumption that the variables used in the regression have the same effects on collateralization decisions across industries. However, this assumption does not always hold. For instance, in an oligopoly like mobile

[10] This note applies to all regression results presented in this paper.

∗: p<0.1; ∗∗: p<0.05; ∗∗∗: p<0.01

All regressions are logistic regressions with binary dependent variable "Collateralized". "Scope" is defined as the number of claim statements a patent has. "Technology" is defined as the number of backward citations a patent has. "Competition" is defined as the number of assignees is the number of patent owners in the technical field the patent is in. The coefficient values are log odds. Standard errors are in parentheses. Data used for the regression are aggregated from Crunchbase company data, U.S. patent data from PatentsView API, and patent reassignment history from USPTO reassignment database. The regression in Column (1) include measures for patent's scope, technology depth, and number of assignees in the technical field. Column (2) to Column (4) remove one of the three variables to examine the explanatory power of each variable. The changes in explanatory power after the removal of variables are measured by change in McFadden's R^2. All regressions use the same set of patent characteristics, firm characteristics controls and industry fixed effects.

telecommunication, the technical competition might play a less significant role than in other industries because the barriers to entry are high, reducing the explanatory power of the competition measure in the industry. Therefore, I further validate the results by running independent regressions on each industry to see how the effects of competition, scope, and technology vary across industries. The result is presented in Table 8. The baseline regression formula used is listed below.

$$\text{Collateralized} = \beta_1 V_{competition} + \beta_2 V_{technology} + \beta_3 V_{scope} + \beta_4 V_{patentControls} + \beta_5 V_{firmControls} + \varepsilon$$

The effects of competition vary across industries, but the positive impact is still evident. For instance, the impact of technical competition on collateralization is much stronger in artificial intelligence than in commerce and shopping, possibly due to the increasing popularity of the Artificial Intelligence technologies, giving the market relatively low barriers to entry. Therefore, it is much easier for patents owned by artificial intelligence companies to lose value than for those held by the companies operating in commerce and shopping industry, which is dominated by large enterprises with high barriers to entry.

After relaxing assumptions on the effect of the variables across industries, the effect of competition in technical field is still significant. Industry-level regressions prove that the results are robust against the effects different industries have on competition. When deciding which patents to use as collateral, competition in their technical fields is a crucial factor affecting decisions.

Table 8: Changes in Explanatory Power of Factors by Industry

Industry	Obs.	R^2	Δ Comp.	Δ Tech	Δ Scope
Apps	1165	0.6306	-0.004	-0.028	-0.0017
Artificial Intelligence	894	0.6689	-0.059	-0.123	0.0002
Commerce and Shopping	1856	0.7881	-0.006	-0.009	-0.001
Community and Lifestyle	761	0.6594	-0.1404	-0.001	-248.931
Consumer Electronics	20922	0.4025	-0.0047	-0.003	0
Consumer Goods	828	0.543	-0.0526	-0.034	0
Content and Publishing	1515	0.6013	-0.0002	-0.027	-0.0015
Data and Analytics	4163	0.2655	0	-0.004	-0.007
Design	1449	0.4541	-0.0255	-0.003	-0.0476
Education	1921	0.7955	-0.0013	-0.003	-0.0079
Energy	11396	0.4385	-0.0038	-1E-04	-0.0004
Food and Beverage	3488	0.3121	-0.001	-1E-04	-0.0011
Gaming	1256	0.4201	-0.0054	-0.003	-0.0005
Hardware	50001	0.2867	-0.0077	-0.003	0
Information Technology	19116	0.3047	-0.0004	-0.001	-0.0006
Internet Services	7945	0.5333	-0.0004	-0.001	-0.0007
Lending and Investments	168	0.8347	-0.0128	-0.035	-0.0013
Manufacturing	23663	0.3244	-0.0116	-1E-04	-0.0021
Messaging and Telecommunications	1124	0.5971	-0.015	-0.033	-0.0055
Mobile	11790	0.1871	-0.0114	-0.033	-0.0001
Natural Resources	1819	0.8008	-0.0006	-0.001	-0.0025
Payments Financial Services	5180	0.7018	-0.0013	-0.002	-0.0003
Privacy and Security	9293	0.2396	-0.0096	-0.002	-0.0007
Professional Services	3683	0.3169	-0.0003	-4E-04	-0.0007
Sales and Marketing Advertising	1425	0.689	-0.003	-0.002	-0.0194
Science Engineering Biotech Healthcare	21654	0.3498	-0.0004	-0.002	-0.0006
Software	38531	0.3626	-0.0051	-0.005	-0.0002
Sports	770	0.4651	-0.0084	-1E-04	-0.0006
Sustainability	4140	0.6057	-0.0189	-4E-04	-0.003
Transportation	15948	0.3873	-0.0031	-0.003	-0.0004
Travel and Tourism	7148	0.383	-0.0004	-1E-04	-0.0007
Video Media and Entertainment	2199	0.501	-0.0032	0	-0.0005

5. Discussion

5.1 Implications of the Results

The results of the regressions show that in addition to patent-level characteristics like technological contribution, the competition in patents' technical field plays a similarly important role when companies decide which patents should be used as collateral.

One significant implication of the finding is that collateralization creates another channel to incentivize innovation. In a more competitive technical field, the inability of patents to deter competitors and the risk of patent infringement lawsuits make it less cost-effective for companies to obtain patents for their innovations. However, the finding of this paper shows technical competition also motivates companies to use these patents as collateral, creating additional financial incentives for companies to continue applying for patents despite their relatively weak effect on company's competitive positions. The possibility of using patents as collateral gives companies an opportunity to obtaining funding needed for operation and R&D. Patent collateralization, therefore, acts as a key mechanism to mitigate the negative effect intense technical competition has on company's propensity to publish their innovations. While the possibility to collateralize intellectual properties motivates companies to continue patenting their innovations despite heated competition, it also gives non-practicing entities (NPEs) opportunities to unjustly threaten companies with lawsuits and deter the company's growth in these competitive fields. NPEs acquire patents in order to threaten companies with patent infringement lawsuits in return for financial settlements. Purchasing patents directly from banks is the main channel NPEs use to acquire their patents. The result in the redemption regressions show that patents in more competitive fields are less likely to be redeemed. This means that it is easier for NPEs to purchase patents that are in competitive fields. Companies in more competitive fields tend to be smaller and therefore more vulnerable to patent infringement lawsuits filed by NPEs. Because of the lack of resource to fight patent infringement lawsuits, the small companies are more likely to pay NPEs for infringement rather than to go through costly lawsuits to determine the validity of NPEs' claims. Therefore, patent collateralization can have mixed effects on the growth of innovations in the economy.

In comparison to competition and technology characteristics of a patent, the scope characteristic has a weaker effect on company's collateralization decisions. One possible explanation is that it is difficult to realize the full value of scope because companies' products might only make use of a subset of the patent's potential application fields. Therefore, the scope does not have a significant effect on company's collateralization decision. In addition, it is interesting to note that a patent with a larger scope is more likely to be collateralized. One possible explanation for the positive coefficient is that patents with wider application fields might be more popular among NPEs, the main purchaser of defaulted patents from banks. With patents that have wider scope, non-practicing entities have a larger range of targets to file patent infringement lawsuits against. Because of greater demand for patents that have large application fields, lenders might favor these patents in the debt financing process, giving "scope" a positive coefficient.

5.2 Limitations

This paper is limited by the factors I consider and the datasets I have access to.

The variables used for the regressions are limited. A variety of technology and scope measures exist, but I use relatively simple definitions of them. It is possible to measure scope not only by the number of claim statements but also by measures obtained from a deeper analysis of patent trees. As for technology characteristic, the backward citations can be discounted to give more weights to citations on more recent inventions. It is also possible to include forward citation as a measure of how much contribution a patent has made to the technical field after its issuance[11]. The method for identifying redemption history in this paper is relatively simple. Using the USPTO patent reassignment data, I identify a release of a security agreement as a redemption. As long as a collateralization record matches a later record marking the release of the security agreement, and the total number of the releases of security agreements is greater than the collateralization records, the patent is coded as redeemed at the time of analysis. The collection of the redemption outcomes is limited by the amount of information provided on USPTO reassignment history. Moving forward, an ideal way to reduce variable bias is to run the same model through a variety of scope and technology measures to validate the results. A more accurate redemption history might be attainable through the dataset maintained by the European Patent Office.

In the analysis of collateralization and redemption decisions, I fail to take into account the effect a worse credit position in case of default might have on bank's patent choice. Therefore, I treat the decisions to collateralize and redeem patents as purely monetary decisions. However, in reality, defaulting on a loan can have a long-term impact on the company's credit ratings and make it more difficult for the company to obtain debt financing and equity financing in the future. The analysis fails to internalize this additional economic cost associated with loan default.

Moreover, I do not consider the roles financial institutions play in the collateralization process. Lender's expertise in dealing with patent collateralizations can significantly impact the type of patents used for collateralization. Lenders who specialize in patent collateralization might have developed a strong expertise in this area, but this analysis fails to control for the effect of financial institutions on the choice of patents to be used as collateral. In addition, financial intermediaries such as venture capital firms that work closely with private companies can significantly impact the collateralization decisions especially for companies in their early stages. With the information provided by effective financial intermediaries, companies might be able to make a more informed decision during the collateralization process. The Crunchbase dataset used for the analysis has limited accuracy because the data are supplied by individuals working in the firms listed in the dataset. A few other datasets exist to complement or replace the Crunchbase dataset. Pitchbook is a company that collects startup funding information. It can provide a more accurate dataset by working directly with venture capital firms and private equity firms to gather information on their portfolio companies. For analysis on public firms, information collection through 10-K can also provide a richer dataset.

5.3 Future Research

Future research can look at the existence of market inefficiencies in the collateralization process. There often is information asymmetry between two sides of debt financing, and patent collateralization is not an exception. Compared to traditional collateral like mortgage, intangible assets give unique challenges to banks because most banks do not yet have expertise in the valuation of intangible assets. The consideration of both sides of debt financing can help better analyze the effect of collateralization on company's propensity to patent innovations. Moreover, more research is needed to better understand how the collateralization process relates to the business activities of non-practicing entities and to minimize NPEs damages on the incentive to patent innovations.

6. Conclusion

By merging company and patent data, I look at the factors affecting company's choice of patents to be used as collateral and find that patents in more technological competitive fields are more likely used as collateral in debt financing. While these patents are less effective at protecting companies from competition, the collateralization presents an alternative means to realize the value of these patents. The possibility of using intellectual property as collateral creates an incentive for companies to continue patenting their inventions disregarding the heavy competition, thus continue improving the stock of knowledge in an economy.

This analysis brings up questions on the roles of financial institutions and non-practicing entities in the collateralization process. Collateralization of patents is a recent development, and market inefficiency exists due to the information asymmetry between creditors and lenders and the lack of regulation on non-practice entities' behaviors. Future research is needed to better understand the best way to incentivize patenting through the collateralization of intangible assets.

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8. REFERENCES

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