NBER WORKING PAPER SERIES

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Working Paper 24370
http://www.nber.org/papers/w24370

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2018

The current version of the paper has benefitted from comments by the Editor (Franco Malerba). The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 24370
March 2018
JEL No. G24,G32,L26,O34

ABSTRACT

It is argued by many that one of the benefits of the patent system is that it creates a property right to invention that enables firms to obtain financing for the development of that invention. In this paper, I review the reasons why ownership of knowledge assets might be useful in attracting finance and then survey the empirical evidence on patent ownership and its impact on the ability of firms to obtain further financing at different stages of their development, both starting up and after becoming established. Studies that attempt to separately identify the role of patent rights and the underlying quality of the associated innovation(s) will be emphasized, although these are rather rare.

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1. Introduction

The question of whether patents are effective as inducements to innovative activity goes back to at least Fritz Machlup's and Edith Penrose's well known comments on the patent system in the 1950s:

> "If national patent laws did not exist, it would be difficult to make a conclusive case for introducing them; but the fact that they do exist shifts the burden of proof and it is equally difficult to make a really conclusive case for abolishing them." (Penrose 1951)

> "If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it." (Machlup 1958)

It is probably safe to say that our overall assessment of the costs and benefits of the patent system today has not advanced much beyond these statements, although we have much greater knowledge about the details of its operation and the sectors in which it is more or less beneficial for innovation.[1]

In addition to the general argument in favor of patents as a way to incentivize innovation by allowing patent owners to exclude those who free-ride on their investments, an additional related argument is that patents are especially useful for new entrepreneurial firms, which have few assets and difficulty signaling their potential to investors. In this article, I survey the limited empirical evidence on the effectiveness of patents in this role, and then discuss the possible negative aspects of this use of patents.

Entrepreneurs are rarely wealthy enough to finance the investment in their ideas that would be necessary to bring them to the market. Therefore they are compelled to turn to external sources of finance, be they angel investors, venture capitalists, banks, or even private equity. Traditionally, the cost of funds for investment in a startup or other new venture could be reduced by the availability of some salvage value for the asset thus created. However, unlike the case of tangible investment, investment in new ideas and inventions does not automatically create property rights for the resulting assets in most cases. In addition, such intangible assets may be harder for investors to evaluate, especially *ex ante*. Hall (2002, 2009) has a fuller discussion of these issues.

Many have pointed out that patents, by creating property rights to the knowledge assets thus created, may be able to lower the cost of finance for investment in ideas. There are at least three distinct ways that obtaining a patent or patent(s) on an invention could reduce the cost of financing its development:

1. Patents can improve the expected profitability of the project, given their role in increasing the appropriability of the returns.
2. Patents, especially if granted, provide an external signal about the quality of the entrepreneur's invention(s).
3. A patent or patents on the idea or knowledge asset may increase the salvage value of an enterprise if it fails and exits. Although failure raises some question about the value of the associated patents, there is plenty of evidence on failing firms that attempt to exploit their patent portfolio when they exit a line of business (some recent examples: Ericsson, Motorola, and Nokia)

Hottenrott et al. (2015) provide some support to this idea as it relates to established firms. Using a sample of approximately 1000 Flemish firms, they find that the ownership of patents reduces the sensitivity of R&D investment to working capital for small and medium-sized enterprises (SMEs), but not for large ones (more than 50 employees). They also find that the citations to these patents have no impact on the relationship, which suggests that patents are important by themselves rather than as proxies for the underlying quality of the invention. However, the number of patents with significant citations is very small, so the latter finding is not very robust.

In this paper I focus on firms for which patents might be expected to be most salient: new entrepreneurial firms in high to medium technology sectors. Economists and legal scholars have recently begun to look at the relationship between patenting, obtaining venture capital funding, and subsequent firm outcomes empirically. Studying these questions is challenging both because the data frequently has to be hand-collected, and also because the same identification problem that affects studies of patent valuation also affects these studies. That is, when a positive effect of patenting is observed, without careful control for the underlying quality of the invention, we cannot tell whether the effect is due to invention quality or the patent right itself (Hottenrott et al. 2015; Hoenig and Henkel 2015).[2] I discuss this issue further after presenting the existing research.

The paper begins with a brief and simple overview of the theory behind the use of patents or other IP to help in financing startups. This is followed by the two main sections that review the empirical literature on the subject: 1) the role of patents in venture capital financing of technology startups, and 2) the functioning of the market that determines the salvage value of patented technology in the case of firm failure or exit from a line of business. The final section concluded with a discussion of what has been learned.

2. Theoretical considerations

Suppose an inventor possesses an idea with the potential to earn profits $\pi>0$. However there is uncertainty about success, which is characterized as a simple probability α, $0<\alpha<1$, such that $E[V] = \alpha\pi$, where V is the value of the project to the potential investor. If the invention is patented before further development, the investor can retrieve a salvage value $0<S<\pi$ in the case of failure, by selling or enforcing the patent. In this case, $E[V] = \alpha\pi + (1\text{-}\alpha)S > \alpha\pi$. So one obvious reason that an investor might prefer a patented idea to a similar unpatented idea is the possibility of limiting losses in case of failure.

Another reason why patenting might be valuable is that it increases profitability because it makes the returns to commercialization of the idea easier to appropriate, leading to a $\pi'=\pi+x>\pi$. Now $E[V] = \alpha\pi + \alpha x + (1\text{-}\alpha)S$, which is larger than $\alpha\pi$ for two reasons: αx from increased profitability and $(1\text{-}\alpha)S$ from the salvage value.

Now assume that the inventor/entrepreneur cannot fully inform the investor of the quality of his idea or his own quality. In this case he may patent in order to signal quality (Spence 1973) as well as for the usual appropriability and salvage value reasons. Spence considers a market with numerous potential employees (in this case, entrepreneurs) of varying productivity who do not enter the market very often, so reputation-building is not worthwhile.[3] The potential employer (venture capitalist) cannot discern the quality of their projects accurately, although the entrepreneurs are better informed. He shows that in this case, if there is a signal whose acquisition cost is negatively correlated with quality or productivity, a number of equilibria may result. One of these equilibria involves high quality types obtaining the signal, while low quality types will find it too costly to obtain. This allows the high quality types to "signal" their quality to the VCs and obtain financing.

Cho and Kreps (1987) show that the so-called "separating" equilibrium of this game is preferred under their intuitive criterion and the criteria of Riley (1979) and Banks and Sobel (1987). Applying this model here requires assuming that obtaining patent(s) is only feasible if the project is of a sufficiently high technical quality. Then the presence of patent filings acts as a signal to the potential investor of the technical quality of the idea. Empirically, of course, there will be many other factors that influence the investor decision, so the prediction is that among a range of startups and controlling for the project and entrepreneur characteristics, those with patent applications or grants will be more likely to obtain external finance, in particular, venture finance.

3. Empirical evidence on financing

Tables A-1 and A-2 in the appendix summarize the empirical papers I review. Table A-1 contains papers that relate patenting to VC-financing outcomes, whereas Table A-2 contains papers that relate performance measures including VC financing to prior patenting. The performance outcomes considered are whether the firm obtains VC funding, how much funding, as well as subsequent firm growth and survival. One reason for including both sets of papers in this review is to highlight the undoubted empirical fact that patenting and VC funding are correlated when one looks across firms. Almost all of these papers find positive correlation in the cross section. To unravel any causal relationship between the two requires a more nuanced examination of the data. Most authors rely on the timing of the activity: that is, whether patent filings precede funding rounds or follow them. A few attempt to use more sophisticated controls.

The research described in these papers covers both the United States and Europe as well as a range of technology sectors: software, semiconductors, biotechnology, nanotechnology, and the internet. The years covered are roughly 1985 to the near present, during a period when the patent system and patenting strategy in some of the sectors, notably software and the internet, evolved (Fink et al. 2016; Hall 2005; Hall and MacGarvie 2010). The firm samples are drawn in a variety of ways. Some consist only of patenters, but the majority includes non-patenting firms, while some contain only VC-backed firms, and others include firms that do not obtain VC funding as well. Thus noncomparability of the results sometimes makes it difficult to draw overall conclusions.

Looking across all the studies, the most striking result at first glance is how few of the firms apply for patents, even in these relatively technology-intensive sectors.[4] Table 1 shows the shares of patenting firms for the studies which contained this information. With the exception of the Israeli study by Greenberg (2013), in no case do more than half the firms have at least one patent application during the period of study. Also shown in the table is the fact that firms in life science and biotechnology areas are more likely to patent than those in computer technology, especially software, as considerable survey evidence has shown (Graham et al. 2009; Cohen et al. 2000). Given the evidence discussed below on the positive association between patenting and firm outcomes, the relatively low patent rates are a bit surprising. Of course, there may be considerable variation in the entrepreneur's or, less often, the VC's understanding or appreciation of the patent system.[5] Alternatively, it may be that the firm had no inventions for which patent protection would be appropriate. This latter argument does suggest that patents are to some extent proxying for quality in these regressions. Graham et al. (2009) surveyed entrepreneurs in the biotechnology and software sectors, finding that reasons for not patenting ranged from cost of obtaining and enforcing a patent and the availability of trade secret protection (especially in software) to fear of disclosing too much information publicly (in biotechnology). Slightly fewer respondents indicated that the invention was viewed as not patentable. These authors emphasize that patenting depends strongly on both the specific technology and the industry of the firm, even for technology startups.

Do patents help in obtaining VC funding? Sichelman and Graham (2010) report on the same large survey of startup and early stage companies in the biotechnology, medical device, and software sectors conducted in 2008. Both companies and expert investors rated financing and improving exit valuation as moderately to very important motives for obtaining patents, more so for biotechnology and medical devices. Interviews with semiconductor manufacturers reported in Ziedonis and Hall (2001) suggest that obtaining financing for startups is the main advantage they see in the patent system, rather than protecting the intangible assets of existing firms. In contrast, managers and IP professionals in this sector see patenting by existing firms as a necessary cost induced by the threat of litigation and the need to cross license in response.

Turning to the direct empirical evidence, both Haeussler et al. (2014) and Farre-Mensa et al. (2016) say yes, patents are helpful for obtaining funding. The former paper studies UK and German biotechnology startups and finds that not only does filing for an EP patent increase the probability of obtaining VC funding, but information revealed during the examination process also influence that probability. The share of X/Y references (threatening novelty) and delays in publishing the search report are negative for VC funding. Opposition to the patent by others increases the hazard of obtaining funding. The authors argue that because the presence of opposition could be both negative (because it is a threat to the patent validity) and positive (suggesting that the invention is valuable), the positive finding means that it is the underlying quality of the invention that is driving VC funding, rather than the simple existence of a patent. Similarly, Engel and Keilbach (2004) examine early stage funding of German startups and find that filing a patent at the German patent office before foundation of the firm strongly predicts later VC involvement with the startup.

Farre-Mensa et al. (2016) use only firms that have filed for their first patent and show that obtaining a grant leads to subsequent firm growth and innovation, and that delay in examination reduces these outcomes. Their paper is unusual in that they have a plausible instrument for the patent grant, which is the examiner-specific prior granting probability. This is unrelated to anything about the current invention other than possibly its technological field (which is controlled for), but clearly related to the grant probability for the patent under consideration. That is, patent examiners have idiosyncratic grant probabilities. This paper provides support for the idea that external patent office validation and the existence of a patent (as opposed to a patent application) are what matter for subsequent performance.

Cockburn and MacGarvie use a different approach, one based on narrowly defined markets. They have data on a number of narrow software markets (e.g., fax software, ATM software, tax software, etc.), some of which were in areas where patents were not issued prior to 1995 (the date of the key software patent decisions such as Alappat) or 1998 (the date of the State Street decision on business method patents).[6,7] They find that in the markets characterized by having large numbers of patents, not having patents delays both VC funding and IPOs, and that this effect is stronger post-1995 (pure software) or 1998 (business methods) for firms in technologies affected by these key court decisions.

Baum and Silverman (2004) ask whether the contribution of venture capitalists is to pick winners, or to assist in developing the startup subsequent to financing it. They find that that characteristics valued for funding are highly correlated with subsequent performance, suggesting that the VCs are good at choosing startups. They also find that the VCs influence the startups after funding by changing the management team once the firm has been chosen. Patent applications have a highly significant impact on the amount of money raised. However, patent grants have less impact, conditioning on applications. This finding is not uncommon – given the high effective grant rate at the USPTO (Quillen et al. 2003; Cotropia and Quillen 2017), the additional information from the grant may not add much, contrary to the Farre-

Mensa et al. findings. However, it does call into question the role of the patent office in certifying the invention quality.

Conti, Thursby, and Rothaermel (2013) focus on the different startup characteristics demanded by VC and angel funders. They use startups that participated in Georgia Institute of Technology's incubator, the majority of which were IT-based. The paper is notable in that they test for and find joint endogeneity between patenting and the initial funding by friends and family, leading them to use instrumental variable estimation to estimate the patenting-funding relationship. They find that contemporaneous US patent applications strongly predict the presence and amount of VC funding, but have less impact on the amount of angel financing obtained. In contrast, angel financing depends on the initial friends and family funding amounts. This result highlights the particular nature of VC funding, which does seem to prefer startups that rely on proprietary knowledge.

Several of the papers condition on being a VC-financed firm. For these samples of firms, the question asked is whether larger amounts or more rounds are financed if the firm has a patent. The earliest paper using this approach is Lerner (1994), who examined VC-backed US biotechnology startups, finding a valuation elasticity of 0.5 with respect to US patent grants. Hsu and Ziedonis (2008) use a sample of VC-backed semiconductor firms and fixed effects models to examine the changes in valuation before each round of financing as a function of the firm's patent application stock. The use of fixed effects means that they control for the average quality of the startup, but not for any information about quality revealed in the course of its progress. They do find that the stock of patent applications increases valuation, especially in the early rounds and when the firm's founders have no prior IPO experience, or when the firm is not financed by a "prominent" VC. The inference is that the patents are serving as a signal of quality when other signals are not available. It is noteworthy that Hsu and Ziedonis found noisier estimates when they used patent grants, as though the grants were not adding as much information, unlike in the Farre-Mensa et al. (2016) sample.

Helmers and Rogers (2011) look at a sample of UK SMEs in high and medium technology industries. Controlling for sample selection due to exit, they find that both 5-year growth and survival increase if the firm has applied for either a UK or EP patent. Growth increases about 26-27 percent per annum given a patent, which is a large number. In contrast, Hall et al. (2013) using a similar sample of UK firms, but one that includes all firm sizes and sectors, finds that employment growth is insignificantly related to patent ownership, although the coefficient is positive. The difference in these results highlights the fact that for SMEs, patents may serve as a more important signal of the future than they do for large firms.

Munari and Toschi (2015) ask whether the amount of VC funding received by nano-technology firms in the first round is related to their patent application holdings. The answer is yes. Interestingly, VCs that specialize in nano-technology only care about nano patents (as indicated by the EPO with a special class, Y01N)[8], while generalists value patent scope as indicated by the number of associated patent classes. This suggests that generalist VCs may be focusing on inventions that have more broad-based applications of nano technology, as one might have expected.

Like Hsu and Ziedonis (2008) and Munari and Toschi (2015), Mann and Sager (2005) focus on venture-backed firms, this time in software. Again, they find that total investment in these firms is related to patents, this time to the number of granted patents (although the grant itself apparently does not matter, at least for the first round of financing). They also find that the number of financing rounds and the survival of the firm are positively associated with patents.

Wagner and Cockburn (2010) focus on a sample of internet-related firms that had an IPO on NASDAQ in the 1998-2001 period. This is a period when many internet firms failed (two-thirds of their sample were delisted by 2005). They find survival associated with having patents, but not with having business method patents, although there are relatively few such patents and the confidence interval is correspondingly large. The usual quality measures (citations, family size, and international applications) did not have much impact on survival, except for a suggestion that having a patent with a large number of cites appeared to increase the probability that the firm was acquired.

An interesting finding in Greenberg (2013) is that Israeli firms that have gone through at least two rounds of VC funding are much more likely to have patents than startups in the other papers reviewed here (see Table 1). The paper confirms that patent applications are associated with higher valuations at each round of funding, except for firms in the software sector. The elasticity of value with respect to US patenting varies across sectors, from 0.08 (insignificant) in software to 0.71 in life sciences, a result that agrees approximately with that of Lerner (1994) for the US. As before in Conti et al. (2013), in the presence of patent applications, patent grants do not matter for valuation.

Using VC-backed US biotechnology startups, Hoenen et al. (2014) are able to show that the impact of patent filings declines after the first funding round, and that grants matter only if applications are excluded. They also find that the usual measures of patent quality (subsequent citations or family size) are not as important. A distinct feature of this paper is that they control for selection into VC funding using a comparable sample of SBIR (Small Business Innovation Research) funded startups and show that sample selection does not affect their results. The equations for the choice of VC funding and its amount are negatively correlated, but not very significantly. They do not include patent filings in the VC selection equation, and the patent grants prior to the first round are insignificant in this equation. Further exploration might be warranted, to see if filings affect the VC dummy as well as its amount.

A completely different approach to this question is taken by Hoenig and Henkel (2015), who survey a large number of venture capitalists to elicit their choices among projects with varying degrees of uncertainty, patenting, team experience, and alliances. They use conjoint analysis to determine that possession of a patent application or grant makes the project more likely to be chosen for funding, but that this likelihood is not higher when the technology quality is unknown. They interpret this result to mean that the signaling aspect of patents is unimportant compared to their role as property rights to the technology.

An important paper by Feldman (2014) reports on the results of a survey of venture capitalists and their portfolio companies. Among other questions, they were asked whether they agreed with the statement “as a venture capitalist, I consider the potential for selling patents to patent assertion entities if the companies fail.” 65 per cent disagreed with this statement, implying that the potential salvage value of the IP associated with the companies they fund does not influence their investment decisions. Of course, this leaves the 18 per cent who agreed with the statement (17 per cent were neutral), so at least some VCs do care about salvage value.[9]

A number of conclusions emerge from this collection of papers. First, it is clear that Venture Capitalists prefer to fund firms that have patent applications underway, even if they are not yet granted. Although informative on its own, the grant does not add a great deal in the presence of applications, largely because the applications happen earlier, and also because the grant probability is quite high, at least in the US, which the majority of these papers studied. However, this conclusion is tempered by the fact that Farre-Mensa et al. (2016) found that within patent filing firms, the grant of a patent does improve their subsequent growth as well as their access to VC funding. Second, there is evidence in a few of these papers that VC funding is more sensitive to patenting in the earlier rounds, when the degree of asymmetric information would presumably be greatest. Third, the papers are rather inconclusive about the reasons that patents and VC funding are related: some emphasize the relationship of patents to the underlying quality of the firm's inventions, while others see the patents as pure signals. Still others emphasize the contribution of the patent grant to appropriability such as Hoenig and Henkel (2015), who use direct survey data to conclude that the associated proprietary right is the important thing for investors, as well as the aforementioned Farre-Mensa et al. (2016).

3.1 Impact of VC finance on patenting

A few of these papers also looked at the impact of receiving VC financing on subsequent patenting (shown in Appendix Table A-2). The majority (Baum and Silverman 2004, Engel and Keilbach 2004, Cao and Hsu 2011) find only a weak or even negative association with VC involvement or the level of financing, controlling for prior patenting. Kortum and Lerner (2000) do find that VC-funded firms patent more, controlling for industry and year. But they do not include controls for patenting prior to receiving funding in this comparison. So their results are not inconsistent with those above.

That is, as discussed in the previous section, patenting is associated with receiving VC funding, but the funding itself provides no further boost to patent filing. This may be as expected, since patents are generally applied for relatively early in the research and development process, and the purpose of obtaining the funding may be to facilitate development of the invention(s) thus protected.

4. Empirical evidence on salvage value

Realizing salvage value from the patents owned by a failing or exiting enterprise requires a functioning patent market. But does one exist? A number of analysts have critiqued the fact that the secrecy with which most patent trades and licensing takes place as preventing the emergence of a robust transparent marketplace. See, for example, Lemley and Myhrvold (2007), who argue forcefully that the development of a market would by facilitated by publication of patent assignment and license terms. Interestingly, although these authors believe transparency would reduce the potential for patent hold-up, Burstein (2015) sounds a cautionary note on patent markets, suggesting that a liquid patent market could lead to more patents rather than more innovation.

A useful lens with which to view the development of a patent market is that provided by Gans and Stern (2010). These authors confront Roth's (2007) pre-conditions for an effective market with insights from the market for ideas or technology. They argue the following: 1) that the market for ideas is not thick because ideas are complementary to assets possibly held by others; 2) that ideas, although non-rival in use, may be rival in value leading to inefficient bilateral bargaining and congestion; 3) that because the user/buyer can reproduce the ideas once known, the market is not safe, as also pointed out by Anton and Yao (2002). All of these features may make a market in ideas/inventions difficult to develop. Gans and Stern go on to discuss the potential for enforceable intellectual property rights to mitigate these problems, concluding that although they may make auctions possible and the market safe, they do not help much with the complementarity problem and may undermine market thickness via enhanced opportunities for hold-up.

In spite of the potential problems in developing an efficient and well-functioning market for patents, the trend today is toward greater trading of these assets, whether via auction-based platforms such as Ocean Tomo, patent brokers, patent pools associated with standards, or simply bilateral cross-licensing. The growth of these activities is undoubtedly related to the increased importance of digital and internet-based technologies, which are complex and require interfacing with technologies developed by others. In this section of the paper I look at the operation of these markets for patents during the recent past, focusing on the cases where the patents have their origin in a firm that is going bankrupt or is exiting the particular market for which the patents are relevant. Because many patent transactions are secret or even if their existence is known, pricing is rarely reported, the picture I obtain here is necessarily only a somewhat partial and hazy one. In addition, existing research tends to identify large firm exit and patent sale rather than failed startups, so it is difficult to determine how many of these are actually involved in value realization from their patents at exit.

Several extreme examples of value realization by large exiting firms exist and have been well-publicized. I give some examples in Table 2. The sellers are either bankrupt (Modu and Nortel), or exiting a particular line of business (IBM, Kodak), or simply in need of funds (Motorola Mobility). For example, Techcrunch reports that the funds from Google will go towards payment of Modu's creditors and ex-Modu employees.[10] The buyers in all these cases are the technology behemoths, who typically purchase these patents as defensive insurance for litigation threats. E.g., the Facebook acquisition of 750 IBM patents was undertaken after Yahoo sued Facebook for infringing 10 patents. Following the patent purchase, the suit was settled with a cross-license agreement between the two firms in July 2012.[11]

With the exception of the Modu sale of 21 U. S. patents, none of the seller firms listed in Table 2 were startups, although they were clearly salvaging some value from their patent portfolio. I therefore turn to the few empirical papers on the market for patent licenses to see whether there is evidence that failed startups are participating in this market.

Agarwal et al. (2015) use data from a survey of potential licensors (creators and owners of IP assets) to assess the role of the Gans and Stern factors in causing deals to fail. They examine three stages in the negotiation: 1) identifying a buyer/seller; 2) initiating negotiations; and 3) reaching an agreement. They find that lack of market thickness and inability to agree the scope of IP reduce the probability of success in phase one, while various bargaining frictions are more salient for phase two. Failure to finally reach an agreement in phase three is more likely to be due to lack of market safety (defined by the authors as the ability to protect by IP) as well as regulatory problems and a lack of trust.

The evidence in this paper supports the idea that IP may help in the market for ideas, but of course is silent on the question of whether this is the optimal allocation of these assets. Because they also find that the firms have a large amount of IP that they are willing to license but do not expect to be able to, it seems that the difficulties in achieving deal success may discourage some potential transactions. The sample of firms studied by Agarwal et al. is drawn from a 2006 survey conducted by the Licensing Foundation, and is unlikely to include many startups.[1] Thus although this research can inform us about the functioning of the IP market, it has little to say about the success startups have in accessing the market.

Love et al. (2017) created a new dataset containing a large number of sales offers by more than 100 patent brokers and online platforms during the period 2012-2016.[12] In all, they study 2605 lots containing 39,000 patents, of which 23,900 were US patents. Approximately three-quarters of the offerings had price guidance attached,

[1] The smallest firms in the sample have at least $500,000 in revenue and R&D, as well as one licensing professtional in their employment. The average firm has $1B-$10B in revenue and between 5,000 and 10,000 employees.

with a mean (median) price of $210K ($150K) per patent, somewhat lower than the values shown in Table 2. Dividing the sellers into five types (individual, PAE, university, defensive aggregator, operating company), they find that two-thirds are operating companies. The most important sellers are AT&T, Xerox PARC, Panasonic, Verizon, Cypress semiconductor, Alcatel Lucent, IBM, Allied Security Trust, Hewlett-Packard, Huawei, and Intel. Although one could argue that some of these are firms exiting a particular line of business, the authors do not present any information that would allow us to identify failed startups among the sellers, although they may be there.

In contrast, Oliver et al. (2016) use similar data to report on 66 transactions across 28 companies during 2010-2015, finding that 71-78% of patent sales occur when the company underperforms the NASDAQ-100 for the two prior years. This lends support to the idea that firms at risk of failing are able to realize value from their patent portfolios, although it does not specifically focus on startups.

There are at least three empirical studies of the best-known patent auction marketplace, Ocean Tomo: Sneed and Johnson (2009), Lee and Lee (2010), and Odasso et al. (2014). Ocean Tomo established the first public auction for IP rights in 2006 and held its first round of auctions through 2008. The last auction in 2009 failed to generate enough interest and the company sold this part of its business to ICAP, which then revived the auctions in 2010. However a check online reveals that the number of lots offered in each auction recently is rather small, and few appear to be sold, especially when compared to the three years 2006-2008 covered by these studies.[13]

Table 3 summarizes the characteristics of the auctions analyzed in each study. The results are fairly consistent, but with some differences due to the choice of specification. Over the 2006-2008 period, the number of lots sold in these auctions averaged just under 50 per cent, and the average lot price ranged from $210 thousand dollars to $357 thousand dollars, for a per patent price that might be about half that, on the low side when compared to the large transactions in Table 2. All of these papers focus on the determinants of patent value in the auction, and thus do not contain much information about the sellers, other than whether or not the seller is a public company, individual, or other. Both Lee and Lee(2010) and Odasso et al. (2014) find that sales of corporate-owned patents are more likely than those for individuals, controlling for technology and other characteristics, but neither include information on the size and the age of the seller.

Summing up, this look at the functioning of the market for IP with respect to its benefits for failed startups is rather inconclusive. There *is* a market, and a number of firms exiting particular technologies have made use of it, but there is very little evidence about the nature of these firms, with the exception of a few well-known large technology firms that attract journalist coverage. Owing to the lack of transparency in parts of the licensing and sale market, the papers reviewed have relied on relatively selective datasets, so the picture is very incomplete. Short of surveying firms about the disposal of their IP as they exit, it is difficult to see how we might obtain a more accurate view of whether the market works for them. Additionally, it must be pointed out that there may be substantive differences between the technologies available from large established firms that are exiting a line of business and those from failed startups. That is, presumably one of the reasons for the failure of a technology-based startup may indeed be that their technology is no longer valuable to anyone else, as well as to the firm itself.

4.1 The dark side of patent markets

The beneficial nature of patent markets or markets for technology presumes that the sale of patents on the "secondhand" market occurs because the technology they protect is useful to a firm other than the one currently owning the patent. In an ideal world, the role of patent markets would be to allocate technologies to those best able to make use of them profitably and efficiently, enhancing overall welfare. However, the evidence on buyers in this market suggests that these patents are being purchased for a range of reasons, most of which do not involve actually using the protected technology. Lemley et al. (2016) suggest that operating companies buy patents for defensive purposes (cross-licensing or counter assertion), to keep them from others who might assert them, or as a part of a merger transaction, and less often for pure licensing reasons. That is, the primary motivation is not usually acquisition of the right to use the covered technology.

In contrast, Non-Practicing Entities (NPEs) buy patents primarily for licensing revenue, and occasionally this leads to litigation. Such sales are a nontrivial portion of the arms-length transactions involving patents. For example, 63% of the lots sold on Ocean Tomo 2006-2008 were purchased by NPEs, who presumably found them potentially valuable for licensing, or perhaps for sale to others. Love et al. (2017) report a similar share of brokered patents (57%) going to patent assertion entities and defensive aggregators. Cotropia et al. (2014) report that about half the patent cases filed in 2012 were filed by NPES (predominantly patent holding companies, but also including individuals, large aggregators, and failed operating companies). In

ICT technologies, the share is even higher, close to 70 per cent. Such transactions would not be problematic if the patents in question contained useful technology, well delineated, and whose boundaries were clear. But numerous scholars have argued that in many cases the patents thus traded suffer from a number of problems that make their enforcement more a matter of rent taxation than the legitimate transfer of technology that might reward its inventors.

Burstein (2005) argues that the relevant question about patent markets is not how to make them more efficient, but whether they enhance innovation or discourage it. He argues that in a world of probabilistic patents and uncertain coverage, patent markets may facilitate trolling and hold-up that is detrimental to innovation on balance.

The problematic factors fall under four interconnected headings: 1) the presence of some low quality patents; 2) the frequency of parallel invention, so that the information in the patent was not used by a potential infringer; 3) bargaining threat points that lead to extraction of more than the value of the patented invention; and 4) actual returns to inventors are rather low. I discuss each of these factors below. But before doing so, I need to caution the reader that this area of research is highly contentious, largely because the various empirical studies struggle with the non-transparency of patent licensing and patent litigation. Many studies are based on survey samples whose precise sampling methodology is difficult to determine, and they often do not contain all the information (especially transaction price information or the costs of settlement outside the court) that would be necessary for a complete study of the costs and benefits of the market. In addition, in the case of patent assertion, we only see the cases that are filed, and not those that are settled before filing. Reflecting the controversial nature of the subject, empirical studies in the area are often the object of critical comments that correct apparent data errors or call into question their methodology.[14]

An interesting recent study by Lemley et al. (2017) attempts to ascertain the size of the patent assertion "iceberg" and finds that among the 30 companies that they surveyed, 70 per cent of the 593 patent assertions against the companies did not proceed to litigation. But even this effort was hamstrung by the understandable reluctance of the authors to probe deep enough to obtain any detail on the nature of the litigated and non-litigated assertions. In addition, the sample was largely based on prior contacts of the authors, who are patent attorneys in Silicon Valley, so it is not a random selection of firms, but one focused on firms in the ICT sector.

In this context, "low quality patents" means those likely to be invalidated or found not to be infringed if they come to trial: they typically have vague claims whose boundaries are uncertain, lack full implementation, or cover subject matter that courts have since ruled ineligible based on the patent statutes.[15] In their book *Patent Failure*, Bessen and Meurer (2009) provide evidence that the fuzzy boundaries of some patents, especially those in the software and business method area, can lead to litigation based on an overly broad reading of the claims in the patent. Lemley and Shapiro (2005) term these kinds of patents "probabilistic patents" in the sense that until a suit comes to trial, their validity and whether infringement has occurred are difficult to determine. The problem is that such patents can be used to extract settlements from potential infringers that are in excess of the actual contribution of the patented technology to the product after a company has sunk other investments in the product. Reitzig et al. (2007) present a model of this kind of behavior. In addition, there is a free-riding problem among alleged infringers, because winning the suit by invalidating the patent benefits all of them, but the cost is born by one (Harhoff et al. 2012, *inter alia*).

In support of the view that NPEs often assert these "probabilistic" patents, Allison et al. (2011) find that when suits come to trial, NPE plaintiffs win less than 10 per cent of the time, in contrast to operating (product) companies, who win 50 per cent of their cases, as suggested by the simplest Priest-Klein (1984) model. However Priest and Klein also show that if the defendant faces a larger loss than the plaintiff's gain, the revealed win probability for the plaintiff will be lower. Therefore, the low win rate suggests that the fact that NPEs face lower trial costs (due to far lower discovery costs than those faced by the operating companies) means that they are willing to pursue even doubtful cases.

Independent invention refers to the situation where an entity is sued for infringement of a patent of which it was unaware, and whose technology it has developed independently of any knowledge of that in the patent. In complex technologies, especially in software, such independent solutions to individual problems encountered in development are common. It is difficult to avoid this eventuality using prior patent search in technologies like those in ICT that are not indexed in a natural way (Mulligan and Lee 2012). Cotropia and Lemley (2009) find that out of 200 infringement cases in Delaware and East District Texas, only 10 per cent allege actual copying (which strengthens a willful infringement charge, so there is incentive so to allege).[16] Almost none of the 10 per cent were in ICT and most were in pharmaceutical and chemical technologies.

Patent markets could encourage innovation by transferring litigation risk from inventors to those more able to bear the risk. For this to work effectively, there should be sufficient returns to inventors via this channel. We have very limited evidence on this question. Bessen et al. (2011) argue that the returns to inventors are small, based on examination of the accounts of 14 NPEs that are public and therefore report their accounts to the Securities and Exchange Commission. However, it is difficult to know how to interpret their numbers: during the 2000-2010 period, these 14 firms paid out $1.7 billion in non-capital investment. This is much less than the stock market losses of $88 billion (as measured by an event study) that were experienced by those they sued. However, it is much more than the net income earned by these NPEs, which was $258 million. Chien (2014) reports that only 9 of the 223 technology startups she surveyed had monetized their patents via licensing or sale, which suggests somewhat limited participation in this market by startups.

Haber and Werfel (2016) conducted a small survey of inventors and entrepreneurs in order to ascertain preferences for the enforcement of patents: in-house or via sale to a PAE. The thought experiment concerned a patent on a product improvement that was valued at one million dollars. The participants were asked to choose between 1) a certain return of $100,000 via sale and 2) various scenarios involving unlimited lawyer time or contingent fee litigation. At these prices, about half of both groups preferred to sell to the PAE rather than paying a lawyer and bearing the risk. However, inventors clearly preferred the contingent fee option, whereas entrepreneurs were indifferent. Although this was only a thought experiment with limited data, it gives some idea of the relatively low return that some inventors require to avoid litigation risk.

Survey and interview evidence of several kinds, as well as a more aggregate study by Kiebzak et al. (2016) support Burstein's (2005) view that a more liquid patent market might not be good for innovation, especially for that by new entrepreneurial firms. Feldman (2014) reports several findings on this question from their survey of VCs: 1) roughly one in three VC-backed startup companies have received demands, higher if they are in the ICT sector; 2) two-thirds of these companies report that all or most of the demands come from PAEs; 3) 58% of these startup companies report that the patent demands had a significant impact; 4) 100 per cent of VCs might refrain from investing if a company faced an existing patent demand. Although it is possible that all these demands were legitimate in the sense that the asserted patents read on the technology, interviews, anecdotal evidence, the experience of VCs, and the fact that the vast majority were in the ICT sector make that unlikely. There is no doubt that the majority of the VCs and companies view the rise of PAEs as negative for their innovative activity.

Chien (2014) surveys 223 technology company startups of which 79 had experienced at least one patent assertion and confirms these views, as well as highlighting the diversity of the responses to a demand. In her sample, the response ranges from doing nothing (22%), shutting down a line of business (9%), settling (18%), fighting in or out of court (35%), or other (16%). She also found significant impacts on the company's operations for about half of those companies with revenues less $100 million. Impacts included distraction from core business, financial impact, delay in hiring or milestones, product changes, and changes in business product lines.

So are patent markets beneficial for innovation? As Haber and Werfel (2016) say in their conclusions:

> "Some studies claim that PAEs extract rents via nuisance lawsuits, thereby placing a direct tax on innovation. An alternative hypothesis is that PAEs are financial intermediaries that facilitate innovation. These hypotheses are not mutually exclusive."

Based on the evidence reported here, I would agree that both views have merit, but the balance varies across firm size and technology. For firms in the chemicals sector and for larger firms, there may be some benefits in being able to monetize patents that are no longer useful in their core business. However, for innovative startups, patent markets may not create much salvage value that benefits the startup in financing, and may instead impose enough costs that innovation in this form is discouraged. The previous statement appears to be especially true in software and business methods, broadly defined.

5 Conclusions

This brief survey has shown the following: in most technology-intensive sectors, patent applications (granted or not) are associated with a number of good outcomes: they help with obtaining VC funding, they increase the amount of funding thus obtained, and they are positively associated with future growth and survival. The only paper that came close to estimating a causal relationship was Farre-Mensa et al. (2016), but that was for grants conditional on having an application.

However, in all cases it was also true that fewer than half the firms in the relevant sample had any patent applications. So the question of whether these patents are simply a proxy for the quality of the underlying firm and its technology, or whether they have value arising from the patent right, becomes important. That is, do the results surveyed suggest that other firms could improve their prospects by applying for patents, or would this be a wasteful activity because their underlying technology is simply not as good as that of the firms that have patent applications?

The second set of findings in the paper concern the functioning of the patent market that would enable technology startups to retrieve value from their patents on exit, an essential ingredient if patents are to be used to secure technology assets for financing. Such markets definitely exist, in several forms, but it is clear that they are plagued by the problems identified by Gans and Stern (2010), among others. Many lots remain unsold, and it seems doubtful that some of the largest transactions are actually technology transfer, rather than defensive maneuvers related to litigation. In addition, the purchasers on some of the markets appear to be dominated by non-practicing entities, whose primary purpose is enforcing the patents against operating companies. Although specializing in enforcement is a legitimate activity, some would question whether it really advances innovation in complex technologies.

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Table 1: Share of firms with patent applications during the study period

Paper	*Sample*	*Sector*	*Share patenting*
Helmers & Rogers (2011)	all UK SMEs	medium & high tech	6%
Cao & Hsu (2011)	US VC-backed	computer-related	7%
Cao & Hsu (2011)	US VC-backed	non-high technology	7%
Cao & Hsu (2011)	US VC-backed	communications/media	9%
Engel & Keilbach (2004)	German VC-backed	all mfg & bus services	10%
Hsu & Ziedonis (2008)	US VC-backed	semiconductors (grants)	14%
Cao & Hsu (2011)	US VC-backed	medical/health/life science	20%
Mann & Sager(2005)	US VC-backed	software	25%
Cao & Hsu (2011)	US VC-backed	semiconductor	26%
Cao & Hsu (2011)	US VC-backed	biotechnology	27%
Munari & Toschi (2015)	global VC-backed	nanotechnology	28%
Hsu & Ziedonis (2008)	US VC-backed	semiconductors (apps)	35%
Greenberg (2013)	Israeli VC-backed	internet	40%
Haeussler et al. (2014)	UK, German VC	biotechnology	40%
Wagner & Cockburn (2010)	US IPO	internet	42%
Greenberg (2013)	Israeli VC-backed	software	54%
Greenberg (2013)	Israeli VC-backed	communications	68%
Greenberg (2013)	Israeli VC-backed	semiconductors	85%
Greenberg (2013)	Israeli VC-backed	life sciences	88%

Table 2: Selected large patent transactions

Date	*Seller*	*Buyer*	*Number of patents*	*Price ($M)*	*Price per patent ($1000)*
May 2011	Modu	Google	21	4.9	233
June 2011	Nortel	Apple/Microsoft consortium	6000	4500	750
August 2011	Motorola Mobility	Google	20000	12500	625
September 2011	IBM	Google	1023	NA	NA
March 2012	IBM	Facebook	750	NA	NA
April 2012	AOL	Microsoft	925	1100	1189
July 2012	Microsoft	Facebook	650	550	846
December 2012	Kodak	Google/Facebook/Apple /Samsung consortium	1100	525	477

Table 3: Ocean Tomo auction studies

Ocean Tomo auction studies

Authors	*Data year*	*Lots*	*Patents*	*Average lot size*	*Share sold*	*Average lot price (US$1000)*	*Sale determinants*	*Pricing determinants*
Sneed & Johnson (2009)	Spring 2006	99	402	4.06	50%	210	smaller scope, smaller family size, younger age *note: no technology control*	broader scope, smaller family, higher forward cites, younger age, smaller lot, individual or university seller
Y-G Lee & J-H Lee (2010)	2007	78	145	1.86	49%	308	smaller scope, corporate seller, larger family size, large number of related bidders, smaller lot size, smaller n of related patents; *limited technology controls*	NA
Odasso et al. (2014)	2006	127	569	4.48	22%	285	corporate seller, higher forward cites, more assignees, technically congruent lot; *technology & year controls*	higher forward cites, more assignees, technically congruent lot. *if seller is NPE*: higher claims, more residual life; *technology & year controls*
Odasso et al. (2014)	2007	172	440	2.56	44%	357		
Odasso et al. (2014)	2008	236	352	1.49	51%	303		
Odasso et al. (2014)	2006-2008	535	1408	2.63	42%	331		

Table A-1: Literature on the impact of patents on VC funding

Author	Date	Title	Country	Industry	Years	Sample	Dep var	Patent var(s)	Results
Baum & Silverman	2004	Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups	Canada	biotech	1991-2000	204 startups/ 471 incumbents	pre-IPO funding; sales, rnd, emply growth; US patent apps & grants; survival	US patent apps & grants by year, plus length of time since last patent (appears to be misspecified)	Do VCs pick winners or build them? Characteristics for funding higly correlated with subsequent performance. Good at picking, but then change mgmt. Patent apps have a highly significant impact on money raised; grants less so in presence of apps
Cao & Hsu	2011	The informational role of patents in venture financing	US	all	1976-2005	22,000 or 10,000 VC-backed startups	D(IPO, bankruptcy, acquired), VC funding, rounds	D(US pat app), N(US pat apps)	Using IV with industry instruments, D(pat) positive for IPO, amt VC investment, negative for bankruptcy & acquisition, patent counts don't matter. Attempt to differentiate between certification and quality is doubtful.
Cockburn & MacGarvie	2009	Patents, thickets, and the financing of early-stage firms: Evidence from the software industry	US	software	1990-2004	software markets; software firms from CorpTech	VC funding; IPO	granted patents in the market; interact with 1995 regime change	Narrow software markets. In thickets markets, lack of patents delays VC funding and IPOs; more after 1995 and 1998
Conti, Thursby, and Rothermael	2013	Show me the right stuff: Signals for High-tech startups	Georgia, US	all - 44% software, only 9% bio/pharma	1998-2008	117 startups in Georgia Tech incubator	D(VC), VC funds, D(angel), angel funds	US patent apps in year	patents strongly predict presence and amount of VC funding contemporaneously, but no impact on angel funding
Engel & Keilbach	2004	Firm level implications of early stage veture capital investment - An empirical investigation	Germany	all mfg + ptt + bus services	1995-1998	142 VC-backed firms; 21,375 non-VC-backed firms	emp growth, D(early stage VC)	German patent apps before foundation	patent filing before foundation date strongly predicts VC involvement later, but VC involvement is only weakly associated with further patenting
Farre-Mensa, Hegde, & Ljungqvist	2016	The bright side of patents	US	all	2001-2014	All first time for-profit unlisted patenters, US-based, no patents 1990-2000	3 and 5 yr E & S growth, acq prob, follow-on innovation, VC funding	D (pat grant); #follow-on pats (# granted); exam delay	Conditional on first patent app; uses examiner assignment instrument; Patents increase growth, jobs, innovation, investor returns, and prob of subsequent VC rounds. Delays in examination reduce this benefit; <10% have VC funding
Greenberg	2013	Small Firms, Big Patents? Estimating patent value using data on Israeli financing rounds	Israel	technology-based	1987-2005	317 tech startups	log valuation at the VC round	US patent granted apps	age and funding year-sector dummies. Elasticity of value to patent apps is 0.46 for non-software (higher for life sciences), nothing for software and for grants, except for very young firms

Table A-1: Literature on the impact of patents on VC funding (cont.)

Author	*Date*	*Title*	*Country*	*Industry*	*Years*	*Sample*	*Dep var*	*Patent var(s)*	*Results*
Haeussler, Harhoff, and Mueller	2014	How patenting informs VC investors - The case of biotechnology	UK; Germany	biotech	2006	all UK/German biotechs that want VC financing	obtaining VC finance	EP pat app stock; share X/Y refs, cites by large tech; share opp.	Filing related positively to VC financing; as is examination process; about 40% have pat apps (more if VC-backed)
Helmers & Rogers	2011	Does patenting help high-tech startups?	UK	high and medium tech	2000	all UK SMEs	growth 2001-2005; survival	D (UK pat app); D(EP pat app)	control for samp sel and simultaneity; patenting increases growth 26-27% per annum (only 6.3% have patents); also strongly correlated with survival
Hoenen et al.	2014	The diminishing signaling value of patents between early rounds of venture capital financing	US	biotech	2001-2011	VC-backed firms and SBIR funded firms	Log of invesment in the round	US pat apps & grants by round	patent apps more important for first round than second; grants seem to matter for second, and when apps excluded. Heckman correction for funding does not affect results. Quality(cites) not as important.
Hoenig & Henkel	2015	Quality signals? The role of patents, alliances, and team experience in venture capital funding	US; Germany	biotech; cleantech; ICT	2011	518 potential VCs (ind assoc.) resulting in 187 obs	choice of firm to fund	patent app or grant	conjoint analysis based on survey of VCs hypothetical choices. Patent app or grant helps, but not more when tech quality unknown - rejects the signaling idea.
Hsu & Ziedonis	2008	Patents as quality signals for entrepreneurial ventures	US	semi-conductors	1975-2005 (founding)	VC only semi-conductor firms	VC investor quality;pre-money value; underpricing at IPO	pat app stock; interacted with early round and no prior IPO exp	focus on signaling aspect of patents pre-IPO and IPO; fixed effects in valuation model; evidence that pats are worth more if less info; about 35% have patent apps; 14% have granted patents
Lerner	1994	The importance of patent scope: An empirical analysis	US	biotech	1973-1992	173 VC-backed firms	valuation of firm in venture financing	patent grants at time of financing round	elasticity about 0.5. Doubling patent grants yields 50% increase in funding; increases in scope similar impact; pooled cross-section
Mann & Sager	2005	Patents, VC, and software startups	US	software	1997-1999 (first round)	VC only software firms	rounds, exit, total inv, survival	granted patents (number & dummies)	only 1 in 4 VC-backed software acquired patents; size of portfolio does not matter; issue before first round does not matter
Munari & Toschi	2015	Do patents affect VC financing? Empirical evidence from the nano-technology sector	global	nano technology	1985-2006	VC financed nano firms	VC financing at 1st round	EP pat apps at first round; all & nano (core)	VC specialists care about nano patents but not other patents. VC generalists care about patent scope (# classes) but not patents
Wagner & Cockburn	2010	Patents and the survival of internet-related IPOs	US	internet	1998-2001 (IPO)	Internet firms with IPO on NASDAQ, 63% VC-backed;	survival from IPO	D (pat app); D(pat app in 705); N of pats with >6 cites	firms with one pat app have a 32% lower prob of exit either via acq or bankruptcy at 5% level; 705 pats do not matter; many cites delay exit via acquisition; only 42% have patents. VC backed firms less likely to fail, more likely to be acquired

Table A-2: Literature on the impact of VC funding on patenting

Author	*Date*	*Title*	*Country*	*Industry*	*Years*	*Sample*	*Dep var*	*Indep var*	*Results*
Baum & Silverman	2004	Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups	Canada	biotech	1991-2000	204 startups/ 471 incumbents	US patent apps & grants	Canadian IRAP seed-capital; pre_IPO financing; time since financing	Canadian seed capital highly correlated with patents; firms with patents receive more pre-IPO funding, but pre-IPO funding not associated with patent apps or grants in the presence of time since patent
Engel & Keilbach	2004	Firm level implications of early stage veture capital investment - An empirical investigation	Germany	all mfg + ptt + bus services	1995-1998	142 VC-backed firms; 21,375 non-VC-backed firms	German patent filings after foundation	D (VC-backed)	patent filing before foundation date strongly predicts VC involvement later, but VC involvement is only weakly associated with further patenting
Kortum & Lerner	2000	Assessing the contribution of venture capital to innovation	US	mfg	1983-1992	2-digit industry data from NSF + Venture economics	granted US pats by app date, contemporaneous with VC funding	VC funding amounts	Using 79 change to pension fund rules as instrument, find that VC funding 3-4 times as productive for patents. Some problems associated with incomplete industry controls.
Cao & Hsu	2011	The informational role of patents in venture financing	US	all	1976-2005	22,000 or 10,000 VC-backed startups	Increase in patent counts after first round of VC	N (US patent apps)	increase in patent counts slightly smaller if VC investment larger, controlling for industry & year; graph shows plateau after receiving investment

Endnotes

[1] See Hall and Harhoff (2012) for a brief survey of the evidence on the patent system-innovation relationship.

[2] In the past, the main empirical approach that is able to distinguish the two effects is that using patent renewal data, which focuses on willingness-to-pay for the patent right (Schankerman and Pakes, 1986). Unfortunately, due to the relatively low level of patent renewal fees, this approach is not able to say much about the upper tail of the value distribution. To date, there is no research using patent renewal fees specifically for the kind of firms that are studied here.

[3] Note that in the VC-funding case, there is evidence that serial entrepreneurs do find it easier to obtain funding, suggesting some form of reputation building (Conti et al. 2013; Baum and Silverman 2004).

[4] An exception is Farre-Mensa et al. (2016), which samples on patenters and focuses on the effect of a patent grant.

[5] See Ito (2005) for one VC's thoughts on the value (or not) of patents to startups.

[6] *In re Alappat* 33 F.3d 1526, 31 USPQ2d 1545 (Fed. Cir. 1995).

[7] State Street Bank and Trust Co., Inc. v. Signature Financial Group, Inc., 149 F.3d 1368 (Fed. Cir. 1998).

[8] Note that this code was discontinued as of 2011 and the nano patents are now classified in B82Y, which is in accordance with both CPC (US) and IPC (international) usage. See http://www.epo.org/news-issues/issues/classification/nanotechnology.html

[9] This paper, like much of the work in this area, is published in a law journal, where the standard for empirical work is somewhat different from that in economics journals. The survey was conducted by mailing VCs one survey and then asking them to distribute a slightly different survey to the companies they funded. Unfortunately, there is no information in the paper about how the sample of 200 is split between VCs and companies, or whether the VC answers are weighted by the number of companies they fund, or even whether the 200 is simply the VC sample.

[10] https://techcrunch.com/2011/05/20/google-spends-4-9-million-on-modu-patent-portfolio/

[11] http://money.cnn.com/2012/07/06/technology/yahoo-facebook-patent-settle/index.htm

[12] Two of the authors on this paper are partners in the Richardson Oliver Law Group, which has a relationship with many buyers in the patent market. This facilitated their access to the broker data, which was obtained under non-disclosure agreements, so there are limits to what they could disclose about particular transactions.

[13] http://icappatentbrokerage.com/2017-summer-catalog

[14] For some examples, see Cotropia et al. (2014), critiqued by Bessen (2014), Bessen and Meurer (2014), critiqued by Schwartz and Kesan (2014), and Lemley and Shapiro (2007a), followed by Golden (2007) and Lemley and Shapiro (2007b).

[15] The key court decision is the U.S. Supreme Court decision in Alice Corp. vs. CLS Bank International (2014), although there are several others that influence the interpretation of the section 101 of the patent statute.

[16] Some also claim that inventors are discouraged from reading patents, especially in ICT technologies, because of the danger of a willful infringement charge in case of litigation, which can carry a threefold increase in damages. The standard for a finding of willful infringement has been a controversial area in the courts, and was also increased in the American Inventors Act of 2012.