# The Economic Meaning of Patent Citations: Value and Organization Form in Patenting Start-ups

by

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*Examination:* This paper is submitted to fulfill the paper requirements of the doctoral oral examination in business and public policy.

*Current Version:* 1st draft, 6th May2011

*Keywords:* Patents, citations, initial public offerings (IPOs), acquisitions, start-ups, property-rights, signaling, technology landscape

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*Abstract:*

We advance three theories of the economic meaning of patent citations and test the predictions they make about firm value and the choice of organizational form for 1,741 start-ups, which secured either an initial public offering or an acquisition from 1986 to 2004. The property rights theory draws on the 'right to exclude' aspects of patents, and considers how firm value would change when patents are viewed as inputs or outputs and when citations behave as complements or substitutes. It also considers how hold-up problems under these various scenarios would affect whether a start-up would prefer to remain independent or be acquired. In contrast to the property rights theory, both a signaling theory and a technology landscape theory view patents as information. These theories make different predictions about firm value and organizational form choice. Our results largely reject both the property rights theory and the signaling theory.

## Introduction

Patents are property rights; rights to exclude usage by other parties for the term of the patent. As such economic theory expects that patents will be valuable to their firms and represent a claim to the future discounted cash flows received from these rights. These cash flows may be divided among many parties; a patent is not a right to use, and the creation of a product embodied by the patent may require the firm to secure other underlying rights. However, at the very least, as patents are costly to acquire[1], the expected benefits should outweigh these costs.

Patents also embody information. A patent filing is a self-contained disclosure of knowledge, which is supposed to be sufficient to describe the invention, and to distinguish it from other inventions. While the USPTO has issued patents that infringe upon other patents, this is probably comparatively rare. Therefore we expect that two patents will not provide exactly the same information. Furthermore, as patents are costly to acquire, they may act as signals of firm value, and some parties may be better placed to interpret these signals than other parties.

The focus of this paper is on the economic nature of citations made and received[2] by patents. A citation is a relationship between two patents. Strictly speaking a patent should cite all relevant 'prior art'. Prior art is the relevant pre-existing knowledge upon which the patent builds, and takes many forms including other patents and academic publications. We focus exclusively on citations to other patents and advance three economic theories for patent-to-patent citations, in each instance inheriting some economic properties from patents.

The first theory builds upon the property rights view of patents. A firm's patent may be an input to its production function or an output. Within this view there are four extreme possibilities. An outside patent may be a complementary input, a substitute input, a complementary output or a substitute output. Furthermore, this outside patent may cite or be cited by the firm's patent, with the direction of citation indicating the temporal precedence. Cited patents that provide complementary inputs are sometimes called blocking patents, and cited patents that create products that are substitutes for the firm's output patents are sometimes called sleeping patents.

Prior to June 8th 1995 patent terms began at the date of issuance and were 17 years, whereas post June 8th 1995, patent terms began at the date of application and were 20 years. To the present day, applicants can deliberately delay the issuance of their patents with a series of continuation applications[3]. However, within the property rights model of citations we will be concerned with identifying which citations are within the term range of the patents in our sample and which are not, as only "in term" patents should matter[4].

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[1] Lemley (2000) estimates these costs at about $25,000 per patent.

[2] We use the nomenclature "citations made" and "citations received", as well as "cited" and "citing", respectively. Other works use backward and forward citations, or even out-degree and in-degree, to mean the same things.

[3] Prior to November 2000, patent applications were not published until they were granted; this combination of situations allowed for submarine patents. An inventor could file for a patent, and have a potentially extended term (through continuances) in which to wait for another party to file for an infringing patent and commercialize their product. As submarine patents will not be cited, we cannot identify their effects.

[4] Inventors are required to cite all prior art, including expired prior art, and failure to do so may threaten both the granting of a patent and the validity of a patent once granted. However, firms do not need to license rights to

The second and third theories build upon the information view of patents. Supposing that patents serve as signals in the presence of information asymmetries about the firm's value, then a cited or citing patent holder might have a better quality signal than other unrelated parties. Likewise, some signals might be stronger or more meaningful than others, and this might be reflected in the citation patterns. We refer to this second theory as the signaling theory of citations. Our third theory is a 'landscape' theory. Under this theory, we suggest that citations are made to inventions that a patent is discrete from but is close to in some fashion. In lay parlance, under the landscape theory, a practitioner would use citations to say "we are over there, but we are not that and we are not that". The landscape theory suggests that citations act as information flows in a general sense that is outside of the realm of property rights or signaling. From a landscape perspective it is perhaps irrelevant that a cited patent's term has expired.

We test these theories concerning the economic nature of citations in the context of startup firms in the United States between 1986 and 2004. Start-up firms that engage in patenting are generally regarded as a crucial source of innovation in the modern economy. We believe that start-ups with patents are as close as possible to the ideal firms that one would want to study if one were to consider whether and how patents create value at the firm level. Patents are considered important to these firms, many of whom epitomize examples from the innovation economy. Microsoft, Google, Sun Microsystems, Palm, NVIDIA, Freescale Semiconductor[5], Genzyme, and Amazon.com, provide everyday examples from various sectors that are in our sample. While the value of these firms is certain not solely in their patents, we expect that their patents will make a significant and economically meaningful contribution to their value.

A start-up might be venture capital-backed, a spin-off from a large incumbent, emerge from a university laboratory, or be financed privately, but when a start-up reaches a certain size and stage of development it will typically either seek an initial public offering on a stock exchange or get acquired by an established firm. It is hard to quantify the fraction of start-up that remain private, but it is almost surely small[6]; in order to compete in the global marketplace firms need access to the large amounts of development capital that an initial public offering or an acquisition can provide.

We regard initial public offerings and acquisitions as a choice of organization form. When we observe an initial public offering we observe that the firm has chosen to remain independent, presumably as the most value can be returned to its shareholders when the firm operates as a standalone entity. Likewise, when we observe an acquisition, first-order economizing suggests that merging the firm with another entity creates the most value for shareholders. We leverage this endogenous choice of organizational form in our analysis. As we will later show, our theories of citations will sometimes make explicit predictions about the firm's optimal choice of organizational form.

Our sample is suited to testing patent characteristics for two reasons. We believe that patents are important to these firms. Our sample consists only of successful start-ups, many of which are in high-technology sectors where patenting is routine – we don't consider the effect of patents for 'failed' startups, whether failure means, for example, the death of a high-tech VC financed start-up or the continued existence of a retail establishment as a privately owned venture. Thus these patents are more

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these patents, as their patent protection has expired.

[5] Freescale Semiconductor was created as a spin-out from Motorola and had an initial public offering in 2004. In robustness checks on our results we consider only venture capital backed start-ups that exclude spin-outs.

[6] It has recently got slightly larger as some start-ups, notably Facebook, have been able to access secondary markets for private equity, but this is outside of our sample range.

likely to be used and of higher quality that other patents. While this will overstate the effect of patents on firm value if one wanted to generalize our results to the population of all firms, it provides an environment where the marginal contributions of patent attributes are most likely to matter. Second we can measure the firm's total value at its liquidity event (its IPO or acquisition). This is the long term value of the firm, not a short-term, stock-return-based measure. The transaction value of an acquisition and the total market capitalization of an initial public offering represent the total future discounted cash flows of the firm, and we will attempt to determine what proportion of these cash flows can be attributed to patent and their characteristics.

**Patent Characteristics**

A patent filing is a structured series of claims, and the number of claims made is often taken as a measure of the patent's breadth (Scotchmer, 2004). For a patent to exist it must be deemed novel and non-obvious. Novelty requires a distinction from the prior art, and a patent's claims demark the areas in which another invention may be equivalent. Therefore, while not all claims are equal in magnitude, one may suppose that the more claims a patent makes the more of the underlying technology space it demarks as its own.

When a patent application is assessed by a patent examiner, the patent is classified in various ways. Every patent must have one and only one original classification which is determined by the class of the controlling claim, or the superior class (i.e. the lowest common higher level classification) if the controlling claim has more than one class. Patents are also given one primary classification which is "indicative of the invention as a whole or the main inventive concept using the claims as a guide" (USPTO, 2010), as well as optional secondary classes and cross-reference classes. The USPTO class scheme is an ever evolving classification system, with classes being born, merging, and becoming redundant over time. Furthermore, classes vary dramatically in their scope and focus, which leads to problems comparing and aggregating patents across classes; the class system has not a systematic overhaul since 1872 (USPTO, 1966). For these reasons, and as there are more than 400 classes for utility patents[7], and more than 100,000 sub-classifications, Hall, Jaffe and Trajtenberg (2001), henceforth HJT, created a standard aggregation of these classes into 6 categories (1-6) and 36 sub-categories (11-69)[8]. There is also an International Patent Classification (IPC) scheme to classify patents, which was used by Lerner (1994) and is supposed to more closely represent the "primary industry and profession"[9] where the patent will be used, rather than being "based primarily on structure and function". We feel that HJT's classification is superior to either the USPTO's or the IPC, and will use it exclusively, though we will note that even in this scheme there will likely be considerable noise.

Patents can be assigned to multiple assignees, and each assignee identity is generally known to us. Ziedonis (2001) exploited this characteristic in a particularly insightful way and constructed a measure of the fragmentation of ownership for the cited patents that we will return to later. The assignees receive the rights of the patent, and can license or sell these rights as they see fit[10]. The USPTO records the type of

[7] We only consider utility patents, which are what most people think of when they think of patents. There are also design patents and plant patents. As our sample begins in 1986, defensive publications are not relevant for us.
[8] The original scheme had 35 sub-categories. Sub-category 25, Electronic Business Methods and Software, was subsequently added under category 2, Computers and Communications, in a revision to the NBER patent data.
[9] For example, IPC class A is "Human Necessities", and class C07 is "Organic Chemistry", which is not deemed a human necessity as the focus is on product industries not function.
[10] Subject to their employment contracts and other legal constraints

assignee; that is whether the assignee is an individual, a university, a corporation, and so forth. HJT report that over 70% of patents between 1963 and 1999 were assigned to US corporations.

Patents are required to make citations to all known relevant prior art. This is a legal duty for the applicant. However, as HJT report, citations could be added by the inventor, a patent attorney, or the patent examiner. It is not possible to infer who added the citations in the NBER patent data, which we use for our analysis[11]. But Alcacer and Gittelman (2004) find that two-thirds of the citations on the average patent are added by examiners and 40% of all patents have all of their citations added by examiners. This is immediately problematic for a property rights theory of citations.

In an NBER book, Griliches' (1998) seminal chapter on "Patent Statistics as Economic Indicators: A Survey" foresees the problem that we are trying to address. He specifically asks "What aspects of economic activity do patent statistics actually capture?"[12]. He surveys the various attempts to establish patents as a measure of R&D activity, before moving on to reporting the literature's findings on how frequently patents are actually used (approximately 50%), and the mean value of a patent conditional on use (about $0.5m in 1988 prices). He then considers the impact of patent portfolios on stock market returns, the only measure of firm value that had been explored at the time. In this last regard Griliches emphasizes that there is a "large noise component in patents as indicators of R&D in the short-run within-firm dimension". In a separate sub-section Griliches briefly explores the use of patents as a measure of spillovers. He suggests that one might want to use "the firm's patenting pattern to construct a measure of its location in 'technology space'".

**The Property Rights Theory**

We begin with the claim that a patent is first and foremost a valuable right. Waterson (1990) provides a model of market entry under the assumption that an incumbent can patent to block off some area of a product space. While Waterson's model focuses on the social costs and benefits to patenting, it provides prima facie support to the notion of a strong private benefit to patenting firms. The literature general supports this with empirical findings in a variety of difference contexts: Griliches (1981) finds a significant positive relationship between the value of a firm and the value of its intangible assets, including patents; Lanjouw, Pakes and Putnam (1998) provide some evidence that patent counts are very imperfect measures of innovation output and hence both private and social value, but that they can be improved substantially by considering renewals; Hall (2005) notes the dramatic growth in patenting post 1984, and finds that the market value of patents is only positive in this period and not before; And Hall, Thoma and Torrisi (2007) find that patents in the US, but not in Europe alone, are valuable, and that business method and software patents are, surprisingly, particularly valuable.

Harhoff, Narin, Scherer and Vopel (1997) and Hall, Jaffe and Trajtenberg (2001) provide the most direct evidence that patents are generally valuable. Harhoff, Narin, Scherer and Vopel (1997) surveyed inventors, and Hall, Jaffe and Trajtenberg (2001) considered the impact of patents on a firm's value through its Tobin's Q, which is the ratio of the market value of the firm to the book value of assets. There

[11] This could be determined for the firms in our sample that filed patents after 2000, and made citations to patents filed after 2000 for some measures, by retrieving the appropriate records from the USPTO website. This would be an obvious extension to the current work.

[12] And points out that this is not the same as asking "What would like them to measure?"

are also a small number of papers that use indirect measures of value. The most notable of these is Trajtenberg (1990). We discuss these papers shortly in the context of the meaning of citations received.

In the context of start-up firms, Mann and Sager (2007) provide a descriptive analysis of 877 software firms that received their first round of venture capital in the boom years between 1997 and 1999. They find that around a quarter of their VC backed software apply for one or more patents, and that patenting varies considerably by sub-industry. However, they are able to demonstrate a correlation between patenting and value, both in terms of the number of rounds a firm receives and the investment made into the firms. More importantly, they find that patents before the first round of investment do not influence the likelihood of receiving subsequent rounds beyond the first round, which they take as evidence that once a patent is filed its future value is fully incorporated in the value of the firm. They state that their paper cannot explicitly consider the role that patents play in venture capital backed firms, but they present their results as consistent with "routine" patenting to extract economic value.

Harhoff, Scherer and Vopel (2003) provide a basic model of how citations may affect property rights. In their model there is a symmetric oligopoly of horizontally differentiated firms, in which a firm can patent an improvement to its product quality. They review three scenarios under the assumption that patent protection is imperfect: a base case in which patents neither block (demark a quality as belonging to a single firm) or provide a substitute and there is no cumulative invention; a case where there is cumulative invention with blocking power for the earlier patent; and a case where there is cumulative invention and a firm can patent a substitute to the earlier patent. From their survey evidence they suggest that blocking patents do occur and matter but that substitutes are rare; specifically out of 69 interviews, approximately one third reported evidence of blocking phenomena, and only two reported evidence of substitutes. While Harhoff, Scherer and Vopel (2003)'s model does not have a production function for the firm, they are clearly modeling earlier patents as inputs to later patents. Thus they are considering citations made as complementary inputs and substitute inputs respectively.

In this paper we do not attempt to derive formal models of our theories; this is left to later work. However we will sketch the outline of each theory. In the case of the property rights model we begin by appealing to Nash Bargaining or an axiomatic bargaining solution concept. Consider a firm with a patent that makes a citation made to a complementary input. A citation is made to a pre-existing patent by definition. Suppose that the firm has an output market for its product where it will earn positive surplus. The cited input can hold-up the production of the product, provided of course that the cited patent is within term, and bargaining would imply that a fair split between the cited input holder and the patent holder is a likely outcome – both will realize positive surplus and neither can do it without the other. As the number of cited complementary inputs increases, so does the number of parties over which the surplus must be fairly split. Therefore the share of value going to the patent holder will be $\frac{1}{N+1}$, where $N$ is the number of cited complementary inputs, and this is decreasing in $N$. This logic holds whether the firm's patent is an input into its production function, or an output product. We might suppose that the share of the value is moderated by the strength of the intellectual property regime, with the consequence that the share of the value going to the patent will be decreasing in $N$ at a lessened rate.

Now consider what happens with perfect substitute inputs. If the firm's patent is an input, and there is a single cited substitute, the firm would be unable to commercialize without its own patent, but once it has its own patent, the cited substitute is only relevant in that the firm can now create a product in a market that is inherently restricted by the cited substitute. If the firm cites two or more other substitute inputs, then Bertrand competition over these inputs makes this argument irrelevant too – the market for inputs that the firm faces is no longer restricted by a monopoly.

If the firm's patent is an output, and there is a single patent as an input, then the patent can't be a substitute. If there is more than one substitute input patent then again Bertrand competition suggests that the firm's output is produced using inputs with no bargaining power. Thus all rents should go to the firm. This is a starkly different prediction from the complementary inputs where the value was decreasing in $N$. In this case, the value increases from $\frac{1}{2}$ of the rents to the full rents as $N$ goes from 1 to 2 or more.

Turning to citations received, the analysis sometime requires an additional assumption – that a new (citing) patent is an improvement over an old one. This may not be true, as while for a new patent to exist it should be different from the old one, it is need not be better. Even though there is a cost to patenting, a patent over a different but inferior technology could still allow a firm access to market that was previously unavailable.

Suppose that a patent is an input to a firm's production function, and that a citing patent is a new complementary input. The old production technology must still be available to the firm as it would be prior art. Thus the firm can still produce using the old technology or can license the new technology. If the firm licenses the new technology it must be (weakly) better off, given its outside option in the bargaining process. The firm is strictly better off if we assume that the new patent is an improvement and that bargaining yields an interior solution. However, while this view is valid, it is somewhat lacking. As HJT point out, citations received are really an inversion of citations made. Firms make citations, and we calculate citations received by looking at the universe of citations made. Therefore it would be more natural to consider that the citing patent is an input into the citing patent holder's production function and the (cited) firm's patent is a complement. Again, this would make the firm's patent more weakly valuable – as it is now in a position to extract rents from the citing patent, or prohibit the citing firm from creating its technology.

If the firm's patent is an output, and the citing patent is a new complementary output, then either the firm's market did not exist until the new patent arrived or the complementary patent has added access to a new market; again in either case the citing patent has added value. However, if the firm's patent is an output and the citing patent is a substitute then we will expect a drop in rents. If the new citing patent is an improvement then the firm has been moved from monopoly rents to at best second-place differentiated product rents, and even if the citing patent is not an improvement, the firm may lose its monopoly rents and instead receive a first-place differentiated product rent.

If cited patents are a mix of complements and substitutes is becomes problematic to make predictions. If two patents are complementary inputs and a third is a substitute for both of them, then Bertrand competition may rule for the complete set. However, if the third is a substitute for some other input (the patent itself perhaps), then the firm will still need to pay rents to two-thirds of its citations made. Similar problems arise when one has a mix of complementary and substitute citing patents.

Overall, we suggest that if Harhoff, Scherer and Vopel (2003) are correct and that substitutes are rare[13], then a property rights model would predict that the more citations a patent makes, the less valuable it will be to its firm, although this must be truncated at the lower bound by the cost of applying for a patent. Likewise we suggest that the more citations a patent receives the more valuable it will be. However, we stress that almost any prediction is possible given different balances of substitutes and complements and given that some citations, and patents themselves, pertain to inputs and others to outputs.

Another dimension to this problem is raised and explored by Lerner (1994), who considers citations made as substitutes to an output. Lerner's unique twist is to consider whether the substitutes are in the same patent class or not. He suggests that patents that act as substitutes to broad range of classes are much more valuable than those are substitutes to only a narrow range of classes. We will replicate Lerner's analysis with two important changes. First we will use the HJT classification for classes and not the IPC, and second we will use an unbiased Herfindahl type measure, described later, rather than a simple count of classes, so that our measure will not convolute a measure of the spread of classes with a measure of citations made.

The empirical evidence on the effect of citations received is mixed. In early work, Trajtenberg (1990) proposed citation weighed patent counts as measures of patent value after finding a strong relationship between citations and social value in Computed Tomography scanner inventions. This was followed by confirmatory results in Harhoff, Narin, Scherer and Vopel (1997) and Hall, Jaffe and Trajtenberg (2001). Harhoff, Narin, Scherer and Vopel (1997) survey inventors on the value of their 964 inventions in the US and Germany and find that inventions reported as more valuable are associated with higher counts of citations received. Harhoff, Scherer and Vopel (2003) re-confirmed the basic results of this work, as well as adding the effects of other patent measures, such as a measure of patent scope, and a measure of the importance of non-patent citations. Hall, Jaffe and Trajtenberg (2001) examined the Tobin's Q of 4800 US manufacturing firms over 30 years and found that citation-weighted patent measures are more highly correlated with the market value of the firm than simple patent stocks. Despite the limitations of using Tobin's Q[14], this paper is often cited[15] as proof that citations received are indicators of value.

However, later work has been more cautious: Sampat and Ziedonis (2004) examine the patent characteristics and value of patents produced by university laboratories. They find that citations are significantly related to the likelihood of licensing but not to licensing revenues; Hall, Thoma and Torrisi (2007) find that citations received provide a small explanation of value only in certain fields, and that for business methods and software patents citations are essentially meaningless; and Bessen (2008) uses renewal data to assess the value of patents, and finds that citations received, the number of claims, and the originality and the generality[16] of patents are all positively and significantly associated with value, though it seems likely that his generality and originality measures were not adjusted for their inherent bias and were therefore convoluted with measures of citations made.

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[13] Again, we insist on some symmetry in our reasoning. Harhoff et. al claim that most citations made are to complements. We cannot then suppose that citations received are from substitutes.

[14] Specifically, Hayashi (1982) shows that Tobin's Q is an ambiguous measures unless one assumes price-taking firms with homogeneous degree one production functions, and studies have used Tobin's Q to measure many things other than the ratio of market value to book value.

[15] At the time of writing Google scholar puts the citation count as 1,160.

[16] These measures consider the spread of citations made and received across classes and are explained in detail later.

In the context of citations made, Jaffe (1986) finds that there are both positive and negative effects on profits and market value from having cited other firms, noting that on balance the effects are positive. This early finding provided a basis for the more elaborate 'thicket' theory, where it is the concentration of ownership among the citations made that matters.

We can extend our reasoning above to capture this quite simply. If we suppose that one negotiates with owners and not individual patents, then most bargaining solutions predict that surplus is split according to ownership identities. That is if one firm has 99 patents and another has one, and both firms are required to create the product, then the rents are split 50:50 and not 99:1. What matters then is not the number of citations made and received but instead the fragmentation of ownership made and received.

Hall and Ziedonis (2001) provide evidence that semi-conductor firms in the US patent extensively, despite not using these patents to appropriate returns. They explain away this paradox with the theory that the firms are patenting to avoid being shut-out of their markets by a patent thicket. That is, they suppose that patents are complementary inputs, and that firms accumulate large defensive portfolios to prevent cited firms from extorting them for rents. Ziedonis (2004) provides some empirical evidence in support of this theory. She explicitly calculates the fragmentation of citations made over ownership for the patent portfolios of 67 semiconductor firms and shows that these firms ultimately patent more (presumably defensively).

On a different tack, Cockburn and MacGarvie (2009) consider 27 carefully defined software markets and the (venture capital backed) start-up firms that enter into them. Using patent count and citation measures, they find that markets associated with patent thickets were less attractive to startups, and provide weak evidence that are less likely to achieve an initial public offering in thicket-dense markets.

If the literature on patent thickets is correct then we will expect two results in our data. First we will expect that all else equal firms that face hold up problems will be less valuable – these firms will have to give away shares of their rents to other parties. And second we expect that firms with either a large number of citations made, or better still highly fragmented citations made over ownership, will seek acquisitions by incumbents with large patent portfolios that can solve their hold-up problems.

In a final property rights take on patents, we consider patents with multiple assignees. Firms with patents that are assigned to both themselves and other entities could be engaging in joint-ventures or other collaborative research. This may make them suitable for acquisition, or for continued cooperation. Gans, Hsu and Stern (2002) find that in certain industries where patents are effective at protecting intellectual property rights and the cost of development is high, innovators tend to earn their rents by acting as an "upstream technology supplier", whereas when patents are ineffective and the cost of development is low, innovators tend to enter output markets and compete head-to-head with incumbents. In the first instance we might observe jointly assigned patents. As cooperation has been sustained already for these firms, there will be less justification for an acquisition. In the second instance there would be no need for a joint-assignment of a patent, and the firm would be a competitive threat that could be solved by an acquisition. Thus we expect that multiple assignments will be positively correlated with initial public offerings.

**The Signaling Theory**

Patents may act as signals in the sense of Spence (1970). That is when firm quality is uncertain and information about quality is private to the firm, the firm can signal its quality to a market of outside investors by taking a costly action that is correlated with high quality, such as filing for a patent. We stress that both uncertainty and information asymmetry are necessary conditions for signaling. If there is no information asymmetry the investors are as informed about the firm's prospects as the firm itself, and, likewise, if there is no uncertainty over the prospects of a venture, there is no information to be revealed. Both the uncertainty inherent in start-ups and the degree of information asymmetry between start-ups and outside investors may vary considerably with both observable and unobservable factors. For instance, one might expect that firms that are attempting to achieve commercialization very quickly, or in markets with high rates of technological change, would face more uncertainty than those that attempt to do so slowly, or in markets that are technologically stable. Similarly, information asymmetries may be higher for certain sectors, or for certain firms, than for others, for example a firm operating in the software industry may know more about its product and prospects than outside investors, but the same may not be true for a retail establishment.

Long (2002) presents a simple signaling model for patents. She states that "Patents can reduce informational asymmetries between patentees and observers. Under some circumstances, the informational function of patents may be more valuable to the rights holder than the substance of the rights". Hsu and Ziedonis (2007) present evidence consistent with the theory that patents have signaling value for startups. They consider a sample of 370 semiconductor firms, from 1980 to 2005 (many of which will be in our sample), and distinguish between the intrinsic value of a patent and the signaling value by comparing the effect of patents on the firm's value for inexperienced and experienced entrepreneurs. Likewise, Haeussler, Harhoff and Muller (2009) examine a self-selected sample of 162 German and 118 US venture capital backed start-up biotechnology firms. Using a hazard rate analysis they find that patents decrease the time to first investment and that venture capitalists appear to pay attention to the quality of patents as measured by citations received. They attribute their results to a signaling hypothesis.

Patents aside, we know from the literature that certification in the presence of information asymmetries is important at both an initial public offering and an acquisition. Kreps and Wilson (1982) provide the economic foundations for how reputations can be used for signaling and certification. Following Megginson and Weiss (1990), who showed that underwriters use their reputations to certify firms at IPO, Gompers and Lerner (1997) showed that venture capitalists[17] can use their reputations to certify their start-up firms to public market investors at exit. Likewise, in the case of acquisitions Brander and Egan (2008) showed that venture capitalists are able to successfully certify their start-up firms to their future acquirers. Returning to patents, Baker (1991) proposed and validated a model where patents were used (by non-VC backed firms) to signal value at IPO.

If patents are signals, how are these signals affected by the patent characteristics? A reasonable starting point might be that patents that either cite more or are cited more provide more favorable information.

[17] Kortum and Lerner (2000) and Hellmann and Puri (2000) provide the seminal references on the relationship between venture capital and patenting by start-ups.

Likewise, a broad patent might signal more favorable information than a narrow patent. If more favorable information translates into more value, then it may be hard to differentiate effective signaling from better property rights when considering the broadness of a patent or the number of citations received, but a distinction could remain for citations made.

While it is no doubt possible to contrive models where uninformed parties finance firms and informed parties don't, we make the assumption that the party with the most information, or the best signal, is the most likely to finance the firm. It is in this context that we feel that a signaling theory could be best tested empirically for our start-ups. Leskovec, Kleinberg and Faloutsos (2005) show that patent networks exhibit homophily – that is that patents with certain characteristics are more likely to cite or be cited by other patents with the same or similar characteristics. Likewise, Jaffe and Trajtenberg (1998) show that patents in the same class are 100 times more likely to cite each other, that patents assigned to the same firm are more likely to cite each and that these citations come sooner than other citations, and that there is geographic concentration in citation patterns. Therefore it seems natural to assume that firms are more likely to be acquired when their patents are in the same class as their acquirer. Given a patent in a certain class, a firm will be better placed to signal its value if it cites narrowly into the technology area that the acquirer understands, and better placed still if it cites its potential future acquirer. Issues of allocative efficiency could presumably be solved through licensing and would not provide a similar justification for organization form choice.

On a different take entirely, Stuart, Hoang and Hybels (1999) show that start-ups with prominent strategic alliance partners succeed faster and secure greater valuations. They attribute this finding to an endorsement effect, which is similar to certification in the presence of information asymmetries. We can measure the extent to which a firm had a strategic alliance by whether its patents were jointly assigned to other corporations. Thus we expect that jointly assigned patents will create value through signaling.

**A Landscape Theory**

Jaffe (1986) pioneered the landscape view of citations, presenting the first evidence that firms' patents, profits, and market value are "systematically related to the technology position" of their research programs. However, it is Jaffe's two seminal and very widely cited papers[18] that use patent citations to measure knowledge spillovers that are now synonymous with aspects of this view. Jaffe, Trajtenberg and Henderson (1993) find that knowledge spillovers have geographic concentration, but that this fades over time albeit slowly. They find no evidence that more basic inventions, that is inventions covered by patents that have a more fragmented class base among their cited patents, diffuse more rapidly. Jaffe and Trajtenberg (1998) extend this analysis to patents in four countries and find that an inventor is up to 80% more likely to cite an invention in their own country and that citations from within a country come faster than international citations.

A landscape theory is different from a signaling theory in that participants are inherently anonymous. This precludes the possibility of strategic messaging, and instead opens up new meanings: Trajtenberg, Henderson and Jaffe (1997) consider how "basic" or "applied" an invention is; the notion of "radical" vs. "incremental" innovations originated with Utterback (1975) and was popularized by Abernathy and Utterback (1978), Dewar and Dutton (1986) and others; "Component" vs. "architectural" innovation was

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[18] Jaffe, Trajtenberg and Henderson (1993) had 3,729 citations on Google scholar at the time of writing.

advanced by Henderson and Clark (1990); various takes on the importance of modularity are provided by the likes of Schilling (2000) and Ethiraj and Levinthal (2004); and Fleming and Sorenson (2004) take a very broad view of patents as markers in a technology that views invention as a recombinant search process. Citation patterns could provide information about the nature of the invention and the process of innovation that is directly relevant to all of these notions.

The biggest problem in constructing a landscape theory is one of construct validity. For a theory to be falsifiable it must make unambiguous predictions, and this requires a clean mapping from the construct to the measure. That is we might consider, as Trajtenberg, Henderson and Jaffe (1997) did, that a measure of the fragmentation of classes-made reflects the basic-ness of the technology, but then we would need to differentiate it from a measure of the radicality, or the architectural-ness, or the modularity, or the search difficulty of the innovation. In this paper will not attempt to make such a distinction, or even properly advance a theory. Rather a landscape theory will be our unspecified explanation of any systematic effect that cannot be explained by either the property rights or the signaling theory. We hope, at the least, to be able to establish a number of stylized facts which a well specified landscape theory must explain. And at the conclusion of this paper we will briefly discuss a next generation of possible measures that we anticipate will help researchers explore such a theory further.

**Measures**

The focus of this paper is on patent-based measures, including the number of patents, as well as derivative measures such as the number of claims made, whether the patent is assigned to multiple corporate entities, and a large variety of citation and network based measures. However, the unit of analysis is a start-up firm, and so all patent measures are used as averages over a firm's patent portfolio.

We will control for various attributes of the firm through-out using fixed effects. These attributes include the exit year of the firm, the industry of the firm as determined by its primary two-digit NAIC code, and the state of incorporation of the firm. The state of incorporation of the form may be important as a large fraction of our start-ups are venture capital backed, and so we have an over representation of firms from California and Massachusetts, so we control for that too. We will also control for the modal sub category of the firm's patent portfolio through-out, in an attempt to reduce the impact of differences in the measures resulting from differences in the class of the innovations. We want to present general results about patenting broadly, not patenting in a specific sector or a specific class. However, we will revisit specific sectors in our robustness checks.

In the exploration of the impact of patent characteristics on organizational form, where the dependent variable will be a binary indicator taking the value one when the firm was acquired and zero when the firm experienced an initial public offering, we will control for the firm value at exit. The firm value is the total purchase price for an acquisition and the market capitalization at the time of the offering for an IPO. As we identified some non-linear effects, we will also control for the square of the firm value in these regressions. Likewise, in the exploration of the impact of patent characteristics on firm value, where the dependent variable will be the natural logarithm of the firm value, we will control for the organizational form using a the binary indicator variable for an acquisition.

**Citation based Measures**

For a firm $i \in \{1, \dots, I\}$, which has a portfolio of patents each indexed by j $\in \{1, \dots, J\}$, we denote the total number of citations from patent $j$ that meet some requirement $k$ in direction $D \in \{Made, Recd.\}$, as $c_{jk}^{D}$. If there is no requirement $k$, then we denote the total citations for patent $j$ in direction $D$ as $c_j^D$. Likewise we denote the total number of patents that firm $i$ holds in its portfolio as $n_i$, and the total number of patents that meet some requirement k as $n_k$.

Through-out our analysis we will use exit-year-based fixed effects. However, these alone will not provide sufficient time controls, given the problems of time-based inflation in our variables. We will also, therefore, create measures for the distance between the filing of our patent portfolio and the firm's exit event. These measures will take the form:

$$\tau_i^D = \frac{1}{n_k}\sum_k (\tau_k^D)$$

where $\tau_k^D$ is the difference, in years, in time between the application of the patent and the exit year. In these measures the requirement $k$ will differ with the major explanatory variable. For regressions where the sample includes all patents in the portfolio, $k$ will be equal to $j$. That is we will consider the average time between application and exit year for the entire patent portfolio. However, if we are considering, for example, a sub-sample of patents that made one or more citations, then $k$ will index the patents that have one or more citations, and we will consider the average time between application and exit year for only these patents.

The fragmentation of ownership is constructed as an average over the patent portfolio, using the unbiased measure provided by Hall (2005) at the patent level. In this measure $k$ denotes identified different owners, excluding the owner of the patent (i.e. excluding self-citations). We are not able to identify the owners of every cited or citing patent in our data. We can identify owners only when patents have a non-zero, non-null assignee number. Furthermore, fragmentation of ownership is meaningless when a firm has no citations in the relevant direction. This is particularly problematic for the fragmentation of ownership received, as citations are right-truncated in our data at 2004. Our fragmentation of ownership measure is:

$$O_i^D = \frac{1}{n_i}\sum_{j=1}^{J}\left(\left(\frac{c_j^D}{c_j^D - 1}\right)\left(1 - \sum_{k \neq i}\left(\frac{c_{jk}^D}{c_j^D}\right)^2\right)\right)$$

Where $\left(1 - \sum_{k \neq i}\left(\frac{c_{jk}^D}{c_j^D}\right)^2\right)$ is the original fragmentation measure, $\left(\frac{c_j^D}{c_j^D - 1}\right)$ is the bias correction term derived in Hall (2005)[19], and $\frac{1}{n_i}\sum_{i=1}^{I}(\cdots)$ takes the average over the patent portfolio. It is important to

[19] As an addendum to Hall (2005) we point out that this bias correction factor is only valid for $c_j^D \geq 2$. When $c_j^D = 1$ the measure is unbiased by construction, so the correction factor is 1, and when $c_j^D = 0$ the fragmentation measure is undefined.

understand that without the bias correction term, the expected value of any fragmentation measure will vary with the number of citations in the appropriate direction. Therefore, a raw measure will convolute the measure of fragmentation with measurement of total citations for a given patent.

The measure of fragmentation of ownership is constructed using one minus the sum of squares of shares of ownership, so that the final measure takes the value zero when ownership is perfectly concentrated, and so that the raw measure tends towards the value one as ownership tends towards perfect fragmentation. With the bias correction factor, perfect fragmentation and just two citations, the final measure tends towards the value two. This ceiling value decreases towards unity as the number of citations increases towards infinity, but the expected mean remains constant irrespective of the number of citations.

The measure of the fragmentation of patent classes is based upon the original measure developed in Trajtenberg, Henderson and Jaffe (1997), henceforth referred to as 'THJ'. THJ named their measure of fragmentation of classes *made* as "Originality", and their measure of fragmentation of classes *received* as "Generality". We refine THJ's measures in two important ways. First, THJ used the USPTO patent classes, where as we use the 36 sub-categories developed in HJT. As discussed previously patent classification is an inherently imprecise art, and using a higher-level scheme should help reduce any effects do to systematic misclassification between certain classes. Second, THJ did not foresee the problem of inherent bias in Herfindahl like measures. We use an unbiased measure. Using $k$ to denote membership in a particular sub-category, our sub category fragmentation measure is defined as:

$$S_i^D = \frac{1}{n_i}\sum_{j=1}^{J}\left(\left(\frac{c_j^D}{c_j^D - 1}\right)\left(1 - \sum_k \left(\frac{c_{jk}^D}{c_j^D}\right)^2\right)\right)$$

Like the fragmentation of ownership measure, the fragmentation of patent sub categories measure tends towards a bias adjustment of unity for citations that are very dispersed across sub categories, and towards zero for citations that are very concentrated across sub categories.

Our measure of technology distance is also adapted from THJ. Our technology distance measure is defined as:

$$T_i^D = \frac{1}{n_i}\sum_{j=1}^{J}\left(\sum_k \left(\frac{T_{jk}^D}{c_j^D}\right)\right) \quad T_j^D = \begin{cases} 1 \; if \; Different \; Category \\ \frac{1}{2} \; if \; Same \; Category \\ 0 \; if \; Same \; Sub \; Category \end{cases}$$

The technology distance, $T_{jk}^D$, between a patent, $j$, and a citation, $k$, in direction $D$, depends on whether the patent are in the same HJT sub category, in which case the distance is zero, the same HJT category, in which case the distance is a half, or in different categories all together, in which case the distance is 1. We then average these distances over the citations, and again over the patents in the portfolio to create a single composite measure of the technology distance between a firms and its citations. This measure is unbiased in its current form.

We also adopted THJ's "distance in time measure", and averaged it over our patent portfolios. Our lag and lead measure is defined as:

$$L_i^D = \frac{1}{n_i}\sum_{j=1}^{J}\left(\sum_{k}\left(\frac{L_{jk}^D}{c_j^D}\right)\right)$$

Where $L_{jk}^D$ is the time, in years, between the application date of patent $j$ and the application date of citation patent $k$.

Finally, we created a new measure called "Percentage of cited patents that make no citations", and averaged it over the firms' patent portfolios. This measure might reflect how close to seminal technologies the firm is under a property rights interpretation, or how sparse the landscape is under a landscape interpretation.

**The Data**

Our primary data source is the NBER patent data which contains data on every utility patent issued in the United States by the USPTO from 1963-2004. This dataset is described in HJT, but we do not use any of the dataset's composite measures. Instead we construct them ourselves from scratch to ensure that the construction is correct[20]. The NBER patent data records all citations post 1975, when citations were first stored in an electronically readable format, and has almost all assignment records for this period too. In total the data contains records on a little over 3.2m patents assigned to 4.86m entities.

Our acquisitions are taken from the SDC Mergers and Acquistions database from 1980 to the present day. We consider only completed acquisitions for 100% of shares of the target firm, where the target was a US private company that was acquired by either a public or private US firm. For acquisitions by public firms above the mandatory disclosure limit[21], this will very closely approximate the population of acquisitions. Privately held firms are sometimes required to disclose material acquisitions under applicable Security Exchange Commission regulations, but not always. Therefore it is less certain that we have something approaching the population for these firms. However, SDC (now owned by Thomson) collects data from surveys and press releases as well as from securities filings, and acquisitions above a certain threshold are very likely to be included. Low-value acquisitions are much more problematic and we will later exclude them from our sample, even though our primary results are robust to their inclusion.

Our data on initial public offerings comes from the GNI New Issues database (now also owned by Thomson). As this data is extracted from offering prospectūs[22] and other mandatory security filings, this data is the population. We consider data from 1986 to the present, prior to 1986 GNI's data collection was not automated. To be included in our dataset, our IPOs must be completed listings on any US exchange, but must not be a Leveraged Buyout (LBO). The firm must be private and never have been public or acquired before its initial public offering (that is we allow spin-offs but not acquisitions followed by spin-

[20] Specifically, we want to determine in-term length citation counts, and construct unbiased versions of Herfindahl type measures (including those for Originality and Generality).
[21] The mandatory disclosure limit varies by exchange and listing type, and is sometimes expressed as a fraction of the acquirer's total assets or other value measure. However, acquisitions above $10m are invariably disclosed across all exchanges and listing types.
[22] The Latin noun prospectus is a part of the fourth declension and so its correct plural is prospectūs.

outs). We also restrict the acquisitions in a similar way. We do not include acquisitions of firms that were private then sought a public listing and then were acquired. As a general rule we take the first of multiple liquidity events.

We then checked that our start-ups included all successful VC backed firms, and marked VC backed firms accordingly. We required that liquidity events took place between 1986 and 2004, and that firms had one or more patents prior to their liquidity event (we only count patents prior to the liquidity event). We only count citations received before the firm's liquidity event, not citations (or patents) received after, as then the choice of organizational form might affect the profile of the patent. Citations received before liquidity events are appropriate because this would be the value measure or the information measure that an acquirer or public investors would see when making their financing decisions. Furthermore, we do not suffer from a truncation issue for citations received before acquisition or IPO, as we restrict to events inside of our patent data.

We also required that the firm was valued between US$10m and US$2.5b inclusive. This involved throwing out 1,672 acquisitions. The lower bound was imposed primarily to remove low value and unrepresentative acquisitions, and the upper bound was imposed as there was only a single acquisition but 36 initial public offerings above this level. The largest acquisition was a little under US$2.7b, and the largest IPO a little over US$77b. We did this in an attempt to ensure common support for IPOs and acquisitions. However, we stress that our main results are unaffected by these choices – we choose to report the most cautious results.

Between 1986 and 2004 there were a little over 2.4m patent applications filed with the USPTO. These applications were assigned to 3.67m assignees. Our final sample of 1,741 successful start-ups filed a total of 19,490 patent applications in this period. Therefore our sample accounts for a material 1% of US patenting, despite accounting for less than 0.05% of the assignees.

We do not have much accounting data for our firms before their liquidity events and only limited data at the events, and some of these variables would have been of interest. Specifically we do not have R&D spending for these firms. Some R&D is directed towards creating patents that will be filed for before the liquidity event, some for patents that will be filed for after the liquidity event, and some for purposes that have nothing to do with patents. We are taking patents to be measures of the future cash flows from the innovation (whether an input or an output) that came from the first component and would not want to include it too. It would be useful to have the second component, as this would measure potential patents, and the third component should be orthogonal to our patents by construction. Not including the second component will overstate the effect of our patents in terms of value in so far as there is outstanding R&D directed towards unrealized patents for these first at the liquidity event, but it should not bias the effects of the derivative measures if we control for the number of patents.

In table 1 below we provide descriptive statistics for our sample. There are several important observations. The first is that many of our measures are skewed. In later analysis we will use the log of these variables to lessen the effects of outliers. However, our main results were not sensitive to these distributional issues. The second important observation is that while our IPOs and acquisitions are similar on most dimensions they appear to differ dramatically with regards to the firm value and the average time between the exit year and the patent year). We include a higher-order term in regressions that use firm value as a control and an indicator for an acquisition when the firm value is the dependent variable in order to mitigate concerns on this issue. Across both IPOs and acquisitions the mean firm value at exit is US$169m, and the mean number of patents accumulated before exit 11.

Table 1: Descriptive Statistics

| | Initial Public Offering | | | | Acquisition | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **N** | **μ** | **σ** | **50%ile** | **N** | **μ** | **σ** | **50%ile** |
| **Common Patent Measures** | | | | | | | | |
| Firm Value | 794 | 241.62 | 350.84 | 114.35 | 947 | 108.84 | 213.31 | 40 |
| No. of Patents | 794 | 12.41 | 46.61 | 4 | 947 | 10.17 | 76.99 | 3 |
| Avg. (Exit Year - Patent Year) | 794 | 3.84 | 3.51 | 2.67 | 947 | 6.05 | 5.02 | 4.2 |
| Avg. Claims Made | 794 | 19.84 | 14.02 | 17 | 947 | 19.59 | 13.79 | 16.6 |
| Multiple Corporate Assignees | 794 | 0.44 | 0.50 | 0 | 947 | 0.32 | 0.47 | 0 |
| Zero Citations Made Indicator | 794 | 0.02 | 0.15 | 0 | 947 | 0.04 | 0.20 | 0 |
| Avg. Citations Made | 794 | 11.43 | 14.77 | 7 | 947 | 10.55 | 15.23 | 7 |
| Zero Citations Recd. Indicator | 794 | 0.01 | 0.12 | 0 | 947 | 0.03 | 0.16 | 0 |
| Avg. Citations Recd. | 794 | 24.56 | 29.50 | 15.55 | 947 | 16.43 | 21.96 | 9 |
| **Derivative Citation Made Measures** | | | | | | | | |
| Avg. Diff. In No. Claims Made | 794 | 4.23 | 12.91 | 2.00 | 947 | 4.38 | 12.97 | 1.84 |
| Avg. Frag. Made (Ownership) | 762 | 0.82 | 0.25 | 0.92 | 888 | 0.82 | 0.25 | 0.93 |
| Avg. Frag. Made (Sub Cat.) | 776 | 0.39 | 0.25 | 0.39 | 903 | 0.39 | 0.26 | 0.40 |
| Avg. Tech Diff. Made | 776 | 0.28 | 0.21 | 0.27 | 903 | 0.28 | 0.22 | 0.25 |
| Avg. Time to Cited | 794 | 5.83 | 2.37 | 5.78 | 947 | 6.24 | 3.01 | 6.14 |
| Pc. Of Cited w/ No Cites | 794 | 0.15 | 0.18 | 0.09 | 947 | 0.16 | 0.21 | 0.09 |
| **Derivative Citation Recd. Measures** | | | | | | | | |
| Avg. Diff. In No. Claims Recd. | 794 | -1.67 | 13.82 | -3.52 | 947 | -1.12 | 13.21 | -2.75 |
| Avg. Frag. Recd. (Ownership) | 284 | 0.21 | 0.34 | 0 | 295 | 0.23 | 0.36 | 0 |
| Avg. Frag. Recd. (Sub Cat.) | 783 | 0.42 | 0.22 | 0.44 | 922 | 0.42 | 0.25 | 0.44 |
| Avg. Tech Diff. Recd. | 783 | 0.31 | 0.20 | 0.28 | 922 | 0.31 | 0.23 | 0.27 |

We will also include a control for the difference between the exit year and the patent year, averaged over the relevant patent portfolio in our regressions. We are employing exit year fixed effects through-out and this is crucial for two reasons: Variable inflation and longer window issues. Practically every one of our independent variables grows over time. That citation counts, both made and received, grow over time is not new; this is reported in Leskovec, Kleinberg and Faloutsos (2005) and others. However, it may surprise readers that unbiased measures of fragmentation of both ownership and sub-categories also increase overtime. We provide plots of four of these variables by exit year in figure 1 below.

In figure 2 below we try to show the importance of 'longer window issues'. Figure 2 depicts two start-up patents, one for an acquisition and one for an initial public offering. The start-up patents both sit on their respective application date lines. The IPO patent is closer to the exit year fixed effect, which means that relative to the acquisition patent it will appear to make more claims, make and receive more citations and cite into a high fragmentation of ownership and classes, all because of variable inflation. It will also have less time (a shorter window) to accumulate citations made before exit, and so without adjustment will have less of them.

Figure 1: Growth of Measures over Time

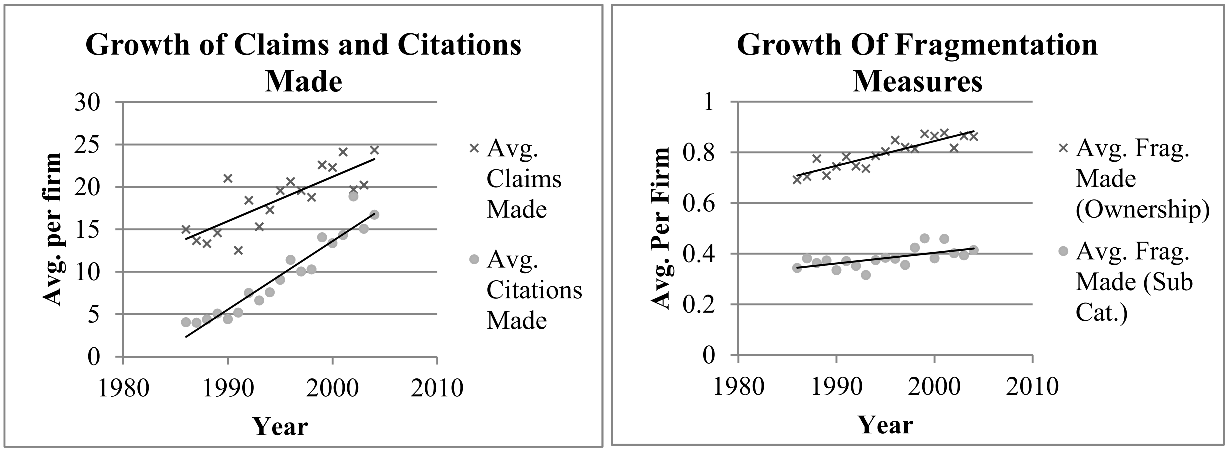
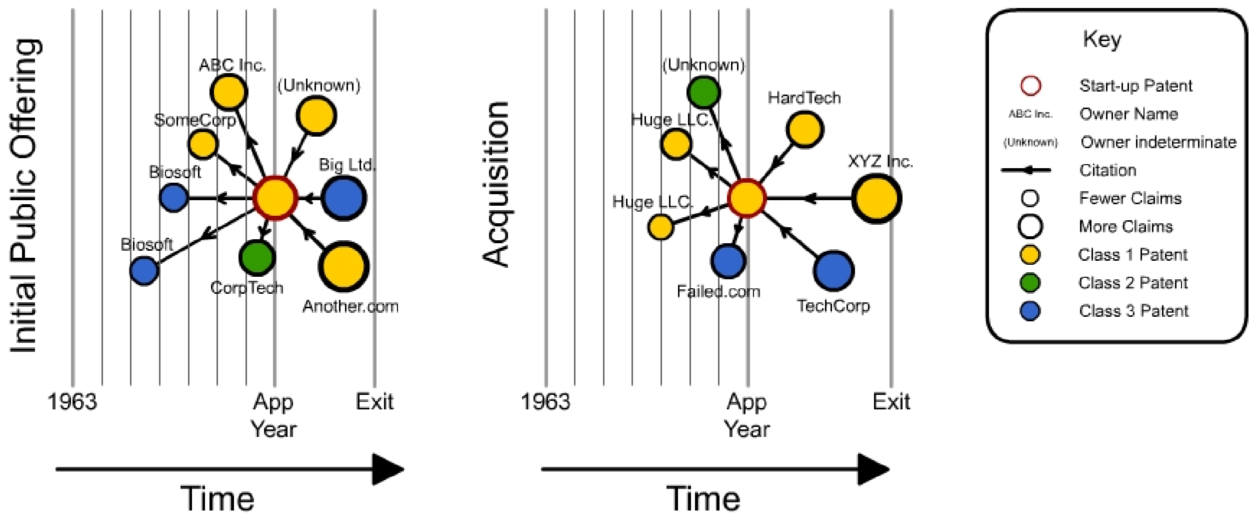



Figure 2: Citations Made and Received for an Initial Public Offering and an Acquisition



**Results and Analysis**

We begin our analysis with an exploration of the log of firm value, in millions of US dollars, using the log of the number of patents, claims made, citations made and citations received, with a full set of controls. As this is a log-log regression coefficients should be interpreted as a one unit change in the raw (not log) independent variable is associated with a coefficient percentage change in the dependent variable. Thus we find that an increase of an additional patent before the liquidity event is associated with a 0.2% change in the value of the firm at the liquidity event. For a back-of-the-envelope calculation, we note that the average firm had a value of $US169m and 11 patents. Therefore we approximate the average firm the change in value attributed to patents to 2.2%, or a little over US$3.7m in absolute terms, making an average patent to an average startup worth about $340,000. This is directly comparable to the evidence recounted in Griliches (1998), which puts 1957 patents values at $473,000 in 1988 prices.

Table 2: Explaining the Value of the Firm using Common Patent Measures

The dependent variable is the natural log of firm value. The coefficients are estimated using Ordinary Least Squares regressions with a Huber-White sandwich adjustment to correct for heteroskedasticity. All columns estimate results using the full sample.

| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Log No. of Patents | 0.207***<br>(0.026) | 0.208***<br>(0.026) | 0.240***<br>(0.036) | 0.218***<br>(0.027) | 0.212***<br>(0.027) |
| Log Avg. No. Claims Made | | -0.012<br>(0.044) | | | |
| Multiple Corporate Assignees | | | -0.119<br>(0.078) | | |
| Log Avg. Citations Made | | | | -0.067<br>(0.043) | |
| Zero Citations Made Indicator | | | | 0.140<br>(0.160) | |
| Log Avg. Citations Recd. | | | | | 0.004<br>(0.034) |
| Zero Citations Recd. Indicator | | | | | 0.289<br>(0.212) |
| Avg. (Exit Year - Patent Year) | 0.002<br>(0.007) | 0.001<br>(0.007) | 0.002<br>(0.007) | -0.006<br>(0.008) | 0.002<br>(0.007) |
| Acquisition Indicator | -1.010***<br>(0.063) | -1.010***<br>(0.063) | -1.011***<br>(0.063) | -1.012***<br>(0.063) | -1.008***<br>(0.063) |
| Exit Year Fixed Effects | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes | yes |
| Constant | 2.767***<br>(0.798) | 2.794***<br>(0.799) | 2.779***<br>(0.791) | 2.872***<br>(0.791) | 2.750***<br>(0.809) |
| R-Squared | 0.315001 | 0.3150364 | 0.3160135 | 0.3168166 | 0.315889 |
| No. Observations | 1709 | 1709 | 1709 | 1709 | 1709 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

We include the log of the number of patents in every specification as we are interested in the marginal effects of patent characteristics beyond the direct patenting effect. The coefficient on the log of the number of patents is very robust to the inclusion of the other measures. Surprisingly, none of our other measures of patents are significant predictors of their firm's eventual valuation at liquidation. Firms with patents that are broader, assigned more widely, cite more, or are cited more, get no valuation premium for these attributes.

In table three we explore the effect on firm value for measures based on citations made. The results are also surprising. We find no effect on effect on firm value when the patent makes more claims than its cited patents, nor when a higher proportion of its cited patents cite no further patents. Both of our fragmentation measures are insignificant: citing a greater spread of classes and owners has no effect on firm value. Citing patents that are at a greater technology distance does reduce firm value with a weekly significant but still economically meaningful coefficient.

Table 3: Explaining the Value of the Firm using Derivative Measures based on Citations Made

The dependent variable is the natural log of firm value. The coefficients are estimated using Ordinary Least Squares regressions with a Huber-White sandwich adjustment to correct for heteroskedasticity. Columns 1 through 3 and column 5 estimate results on the sub sample of firms that made at least one citation. Column 4 estimates results on the sub sample of firms that make at least one citation to an identified owner.

| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|---|---|---|---|---|---|---|
| Log No. of Patents | 0.212*** (0.027) | 0.210*** (0.027) | 0.211*** (0.027) | 0.215*** (0.027) | 0.212*** (0.027) | 0.217*** (0.027) |
| Avg. Diff. In No. Claims Made | 0.001 (0.002) | | | | | |
| Avg. Frag. Made (Sub Cat.) | | -0.152 (0.117) | | | | |
| Avg. Tech Diff. Made | | | -0.25* (0.134) | | | |
| Avg. Frag. Made (Ownership) | | | | -0.103 (0.117) | | |
| Avg. Time to Cited | | | | | -0.030** (0.013) | |
| Pc. Of Cited w/ No Cites | | | | | | 0.154 (0.181) |
| Zero Citations Made Indicator | | | | | | 0.077 (0.165) |
| Log Avg. Citations Made | | | | | -0.052 (0.042) | -0.061 (0.041) |
| Avg. (Exit Year - Patent Year) | -0.005 (0.010) | -0.006 (0.010) | -0.005 (0.010) | -0.011 (0.010) | -0.013 (0.010) | -0.013 (0.011) |
| Acquisition Indicator | -1.026*** (0.064) | -1.030*** (0.064) | -1.030*** (0.064) | -1.028*** (0.064) | -1.027*** (0.064) | -1.013*** (0.063) |
| Exit Year Fixed Effects | yes | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes | yes | yes |
| Constant | 2.930*** (0.824) | 2.978*** (0.805) | 3.009*** (0.810) | 3.401*** (0.824) | 3.112*** (0.843) | 2.891*** (0.803) |
| R-Squared | 0.3161913 | 0.3174404 | 0.3182879 | 0.3244095 | 0.3199837 | 0.3172262 |
| No. Observations | 1651 | 1648 | 1648 | 1619 | 1651 | 1709 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

The only measure that seems to properly matter is the average time in years between the patent and its cited patents. The longer this period the less additional value firm a firm gets from its patents. Although this coefficient is small at -0.03%, using an average firm calculation, this would result in an average of decrease in value of $50,000 for each additional year.

Table 4: Explaining the Value of the Firm using Derivative Measures based on Citations Received

The dependent variable is the natural log of firm value. The coefficients are estimated using Ordinary Least Squares regressions with a Huber-White sandwich adjustment to correct for heteroskedasticity. Column 1 estimates results using the full sample. Columns 1 through 3 estimate results on the sub sample of firms that made at least one citation. Column 4 estimates results on the sub sample of firms that make at least one citation to an identified owner.

| | Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|---|
| Log No. of Patents | 0.215***<br>(0.027) | 0.216***<br>(0.027) | 0.216***<br>(0.027) | 0.278***<br>(0.051) |
| Avg. Diff. In No. Claims Recd. | 0.000<br>(0.002) | | | |
| Avg. Frag. Recd. (Sub Cat.) | | -0.111<br>(0.125) | | |
| Avg. Tech Diff. Recd. | | | 0.013<br>(0.132) | |
| Avg. Frag. Recd. (Ownership) | | | | 0.151<br>(0.155) |
| Avg. (Exit Year - Patent Year) | -0.001<br>(0.007) | -0.001<br>(0.007) | -0.001<br>(0.007) | 0.011<br>(0.021) |
| Acquisition Indicator | -1.006***<br>(0.063) | -1.004***<br>(0.063) | -1.006***<br>(0.063) | -0.966***<br>(0.121) |
| Exit Year Fixed Effects | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes |
| Constant | 2.818***<br>(0.803) | 2.822***<br>(0.797) | 2.808***<br>(0.801) | 3.353***<br>(1.194) |
| R-Squared | 0.3178953 | 0.3188288 | 0.3184675 | 0.4206767 |
| No. Observations | 1675 | 1674 | 1674 | 564 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

Table 4 is even more surprising. Once we control for the number of patents, the citations received based attributes have no meaningful effect on firm value. In fact, not a single measure has a coefficient that is less that its standard error, which would suggest that these measures are simply noise.

In table 5 we examine the choice of organizational form.

Table 5: Explaining Acquisitions with Common Patent Measures

The dependent variable is a binary indicator that takes the value one if the firm experienced an acquisition and the value zero if the firm undertook an initial public offering. The coefficients are estimated with logit regressions that correct for heteroskedasticity. All columns estimate results using the full sample.

| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Log No. of Patents | -0.250***<br>(0.064) | -0.252***<br>(0.065) | -0.201**<br>(0.088) | -0.239***<br>(0.066) | -0.251***<br>(0.065) |
| Log Avg. No. Claims Made | | 0.039<br>(0.107) | | | |
| Multiple Corporate Assignees | | | -0.169<br>(0.197) | | |
| Log Avg. Citations Made | | | | -0.280***<br>(0.101) | |
| Zero Citations Made Indicator | | | | -0.993*<br>(0.549) | |
| Log Avg. Citations Recd. | | | | | -0.063<br>(0.085) |
| Zero Citations Recd. Indicator | | | | | -0.436<br>(0.486) |
| Avg. (Exit Year - Patent Year) | 0.143***<br>(0.022) | 0.144***<br>(0.022) | 0.143***<br>(0.022) | 0.130***<br>(0.025) | 0.143***<br>(0.022) |
| Firm Value | -0.008***<br>(0.001) | -0.008***<br>(0.001) | -0.008***<br>(0.001) | -0.008***<br>(0.001) | -0.008***<br>(0.001) |
| Firm Value Squared | 0.000***<br>(0.000) | 0.000***<br>(0.000) | 0.000***<br>(0.000) | 0.000***<br>(0.000) | 0.000***<br>(0.000) |
| Exit Year Fixed Effects | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes | yes |
| Constant | -4.011**<br>(1.885) | -4.094**<br>(1.903) | -4.109**<br>(1.881) | -3.848**<br>(1.953) | -3.781**<br>(1.926) |
| R-Squared | 0.3606838 | 0.3607363 | 0.3609995 | 0.3646742 | 0.3610728 |
| No. Observations | 1673 | 1673 | 1673 | 1673 | 1673 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

Table 6: Explaining Acquisitions with Derivative Measures based on Citations Made

The dependent variable is a binary indicator that takes the value one if the firm experienced an acquisition and the value zero if the firm undertook an initial public offering. The coefficients are estimated with logit regressions that correct for heteroskedasticity. Column 6 estimates results using the full sample. Columns 1 through 3 and column 5 estimate results on the sub sample of firms that made at least one citation. Column 4 estimates results on the sub sample of firms that make at least one citation to an identified owner.

| ma | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|---|---|---|---|---|---|---|
| Log No. of Patents | -0.211*** (0.066) | -0.213*** (0.065) | -0.212*** (0.066) | -0.223*** (0.067) | -0.182*** (0.067) | -0.185*** (0.065) |
| Avg. Diff. In No. Claims Made | 0.004 (0.005) | | | | | |
| Avg. Frag. Made (Sub Cat.) | | -0.255 (0.281) | | | | |
| Avg. Tech Diff. Made | | | -0.325 (0.323) | | | |
| Avg. Frag. Made (Ownership) | | | | -0.228 (0.313) | | |
| Avg. Time to Cited | | | | | 0.064* (0.035) | |
| Pc. Of Cited w/ No Cites | | | | | | 0.892* (0.489) |
| Zero Citations Made Indicator | | | | | | 0.382 (0.530) |
| Log Avg. Citations Made | | | | | -0.447*** (0.103) | -0.373*** (0.096) |
| Avg. (Exit Year - Patent Year) | 0.161*** (0.030) | 0.160*** (0.030) | 0.162*** (0.030) | 0.169*** (0.033) | 0.143*** (0.031) | 0.115*** (0.033) |
| Firm Value | -0.008*** (0.001) | -0.008*** (0.001) | -0.008*** (0.001) | -0.008*** (0.001) | -0.008*** (0.001) | -0.008*** (0.001) |
| Firm Value Squared | 0.000*** (0.000) | 0.000*** (0.000) | 0.000*** (0.000) | 0.000*** (0.000) | 0.000*** (0.000) | 0.000*** (0.000) |
| Exit Year Fixed Effects | yes | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes | yes | yes |
| Constant | -4.366** (1.891) | -4.270** (1.931) | -4.275** (1.929) | -2.088 (1.952) | -4.291** (1.998) | -4.261** (1.952) |
| R-Squared | 0.3609358 | 0.3611726 | 0.361227 | 0.358504 | 0.3693526 | 0.3620909 |
| No. Observations | 1610 | 1607 | 1607 | 1572 | 1610 | 1673 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

Table 7: Explaining Acquisitions with Derivative Measures based on Citations Received

The dependent variable is a binary indicator that takes the value one if the firm experienced an acquisition and the value zero if the firm undertook an initial public offering. The coefficients are estimated with logit regressions that correct for heteroskedasticity. Columns 1 through 3 estimate results on the sub sample of firms that made at least one citation. Column 4 estimates results on the sub sample of firms that make at least one citation to an identified owner.

| | Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|---|
| Log No. of Patents | -0.249***<br>(0.065) | -0.250***<br>(0.065) | -0.251***<br>(0.065) | -0.430***<br>(0.132) |
| Avg. Diff. In No. Claims Recd. | 0.006<br>(0.005) | | | |
| Avg. Frag. Recd. (Sub Cat.) | | 0.267<br>(0.316) | | |
| Avg. Tech Diff. Recd. | | | 0.177<br>(0.349) | |
| Avg. Frag. Recd. (Ownership) | | | | -0.132<br>(0.393) |
| Avg. (Exit Year - Patent Year) | -0.145***<br>(0.023) | -0.144***<br>(0.023) | -0.144***<br>(0.023) | -0.306***<br>(0.062) |
| Firm Value | -0.008***<br>(0.001) | -0.008***<br>(0.001) | -0.008***<br>(0.001) | -0.008***<br>(0.002) |
| Firm Value Squared | 0.000***<br>(0.000) | 0.000***<br>(0.000) | 0.000***<br>(0.000) | 0.000***<br>(0.000) |
| Exit Year Fixed Effects | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes |
| Constant | -3.941**<br>(1.890) | -3.961**<br>(1.896) | -3.984**<br>(1.904) | 5.447***<br>(1.986) |
| R-Squared | 0.3582795 | 0.357789 | 0.3575926 | 0.421844 |
| No. Observations | 1640 | 1639 | 1639 | 512 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

Table 8: Explaining Acquirer Patenting with Citations Made and Fragmentation of Ownership Made

For columns 1 through 3 the dependent variable is an indicator that takes the value one if the acquirer had any patents at the time of the start-up's exit, and zero otherwise. The coefficients are estimated using a logit regression with that corrects for heteroskedasticity. These results are estimated on the complete subsample of acquisitions. For columns 4 through 6 the dependent variable is the natural log of the number of the acquirer's patents. The coefficients are estimated using Ordinary Least Squares regressions with a Huber-White sandwich adjustment to correct for heteroskedasticity. These results are estimated on the subsample of acquisitions where the acquirer had one or more patent at the time of exit.

| | Acquirer has Patents Indicator | | | Log of No. of Acquirer Patents | | |
|---|---|---|---|---|---|---|
| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
| Log No. of Patents | 0.036<br>(0.071) | | | 0.189<br>(0.123) | | |
| Log Avg. Citations Made | | 0.150<br>(0.130) | | | 0.060<br>(0.165) | |
| Zero Citations Made Indicator | | -0.342<br>(0.533) | | | -0.460<br>(0.667) | |
| Avg. Frag. Made (Ownership) | | | 0.224<br>(0.378) | | | -0.841<br>(0.524) |
| Avg. (Exit Year - Patent Year) | -0.053***<br>(0.019) | -0.033<br>(0.028) | -0.044<br>(0.028) | -0.036<br>(0.029) | -0.020<br>(0.042) | -0.050<br>(0.045) |
| Exit Year Fixed Effects | yes | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes | yes |
| State Fixed Effects | yes | yes | yes | yes | yes | yes |
| Sub Cat. Fixed Effects | yes | yes | yes | yes | yes | yes |
| Constant | 3.666**<br>(1.618) | 3.341**<br>(1.647) | 2.398<br>(1.824) | -6.452***<br>(1.580) | -6.254***<br>(1.602) | -5.026***<br>(1.720) |
| R-Squared | 0.1625839 | 0.1599861 | 0.1566642 | 0.314229 | 0.3085581 | 0.3103374 |
| No. Observations | 891 | 891 | 836 | 453 | 453 | 434 |

Standard errors are reported in parentheses. ***, **, and * indicate significance at the p=0.01, p=0.05 and p=0.1 levels respectively.

## Robustness Checks

- Effects of firm value on IPO/Acquisition
- VC backed firms only
- Startups with a single patent
- Specific Industries

## Conclusion

- Short summary of major theories and results
- Network measures as the next step for Landscapes

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