Do Patents Facilitate Entrepreneurs' Access to Venture Capital? * †

Joan Farre-Mensa
Harvard Business School

Deepak Hegde
Stern School of Business
New York University

Alexander Ljungqvist
Stern School of Business
New York University
and *NBER*

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† Address for correspondence: Harvard Business School, Rock 218, Boston MA 02163. Phone 617-495-6963. e-mail jfarremensa@hbs.edu (Farre-Mensa). New York University, Stern School of Business, Suite 722, 40 West Fourth Street, New York NY 10012-1126. Phone 212-998-0674. e-mail dhegde@stern.nyu.edu (Hegde). New York University, Stern School of Business, Suite 9-160, 44 West Fourth Street, New York NY 10012-1126. Phone 212-998-0304. e-mail al75@nyu.edu (Ljungqvist).

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Abstract

We investigate the role that patents play in helping innovative startups finance their growth. We show that the approval of a startup's first patent application increases its likelihood of raising venture capital (VC) funding in the following three years by 3.5 percentage points—a 59% increase relative to the unconditional probability of raising VC funding. Our identification strategy exploits plausibly exogenous variation in the propensity of quasi-randomly assigned patent examiners to approve applications using a comprehensive sample of 33,855 first-time patent applicants. Patents are particularly beneficial to early-stage startups, those founded by inexperienced entrepreneurs, those located in states with a large startup population, and those operating in the IT sector. This evidence suggests that patents help mitigate information frictions between startups and investors, acting as catalysts that help set startups on a path to success and more than doubling their unconditional IPO probability.

JEL classification: G24, D23, L26, O34.

Startups often face considerable constraints on their ability to finance their growth, owing to patchy track records, potentially severe information asymmetries, and inadequate collateral.[1] Financing frictions tend to be particularly severe for innovative startups aiming to commercialize new ideas for which precedents are limited. In this paper, we investigate empirically whether and to what extent patents help innovative startups overcome frictions in the market for entrepreneurial capital.

Prior work emphasizes at least three ways in which patents might help. First, by vetting the claimed benefits and originality of the invention, a patent review can certify the quality of the entrepreneur's idea, reducing information asymmetries between the startup and investors (Long 2002; Hsu and Ziedonis 2013). Second, by granting a property right on the startup's invention, a patent can reduce the risk to the entrepreneur of her idea being expropriated, allowing her to share details of the idea with investors more freely (Arrow 1962; Bhattacharya and Ritter 1983; Biais and Perotti 2008). Third, by codifying the invention, a patent can turn an idea into an asset that can be pledged as collateral, reducing adverse selection and moral hazard problems in the market for entrepreneurial debt (Chava, Nanda, and Xiao 2015; Hochberg, Serrano, and Ziedonis 2015; Mann 2015).

The extent to which patents help startups overcome financing frictions in practice is an open empirical question. The difficulty in answering it is largely due to endogeneity: better entrepreneurs, and those with better ideas, are simultaneously more likely to obtain patents and to raise funding. Unobserved differences in an entrepreneur's background or expertise and in the ex ante quality of her invention may thus explain why some innovative startups fail to obtain both a patent and funding while others succeed. In other words, patent grants themselves may

[1] See Evans and Jovanovic (1989), Black and Strahan (2002), Cagetti and De Nardi (2006), Kerr and Nanda (2011), Adelino, Schoar, and Severino (2015), and Schmalz, Sraer, and Thesmar (2015).

play no causal role in helping a startup raise external capital. This identification challenge is compounded by the fact that, until recently, rejected patent applications were not observable, thus making it impossible to distinguish between firms that tried but failed to patent, and those that chose not to patent or not to innovate altogether.

To overcome these challenges, we exploit institutional features of the U.S. Patent and Trademark Office's (USPTO) review process to create an instrumental variable (IV) for whether or not a patent application is approved. We combine this instrument with proprietary data from the USPTO's internal databases and create a comprehensive sample of 33,855 startups that have applied for patents between 2001 and 2009 and that have received a final decision—positive or negative—by December 31, 2013. We then ask whether obtaining a patent helps a startup raise capital from venture capital (VC) firms.[2]

Our identification strategy exploits exogenous variation in patent examiners' approval rates to instrument for the probability that an application is approved.[3] The validity of the IV rests on two features of the review process. First, the USPTO assigns applications in each technology field ("art unit") to patent examiners based on their predetermined workloads. Thus, after conditioning on art unit-by-application year fixed effects, which examiner an application is assigned to is effectively random with respect to applicant or application quality (Lemley and Sampat 2012; Sampat and Williams 2015). Second, examiners vary in their propensity to approve applications: some are more lenient while others are stricter (Cockburn, Kortum, and

[2] Venture capital is not the only source of funding for startups, but as prior work has shown, it is particularly useful to the kinds of innovative startups we focus on (Hellmann and Puri 2000; Kortum and Lerner 2000; Gompers and Lerner 2001). In addition to offering funding, VCs provide monitoring and advice (Hellmann and Puri 2002; Bernstein, Giroud, and Townsend 2015), access to networks of potential customers, suppliers, and strategic partners (Hochberg, Ljungqvist, and Lu 2007), and help recruiting talented individuals (Gorman and Sahlman 1989).
[3] Sampat and Williams (2015) first used a version of this instrument to measure the effect of gene patents on follow-on scientific research and product development related to that gene. In a recent working paper, Gaule (2015) uses a similar instrument to study the effect of patents on the likelihood of going public or being acquired using a sample of 2,191 VC-backed startups.

Stern 2003; Lemley and Sampat 2012). Together, these two features result in the quasi-random assignment of similar applications to examiners who differ in their propensity to approve patents.

Our analysis shows that patents play a sizeable role in helping startups raise external capital. After instrumenting patent approval, we find that startups whose first patent application is approved are 3.5 percentage points more likely to raise VC funding over the next three years than those whose first application is rejected. This approval effect represents a 59% increase over the 5.9% unconditional probability of raising VC funding in our sample.

Consistent with the notion that patents help alleviate information frictions between startups and investors, we find that the effect of patents on VC funding is strongest for startups liable to the greatest frictions. Specifically, the patenting effect is larger for startups with little or no prior VC funding, those founded by inexperienced entrepreneurs, and those located in geographic areas with intense competition for startup capital. We also find a larger effect in the IT sector, where, unlike in pharma or biotech, startups tend to be founded by young entrepreneurs without an academic track record that can be used to predict the quality of their innovations (Ewens, Nanda, and Rhodes-Kropf 2015; Li and Agha 2015).

The beneficial effects of obtaining a patent are not limited to raising venture capital. Startups whose first patent application is approved are close to twice as likely to subsequently have a successful exit for their founders and investors (in the form of an IPO or an acquisition). This effect is driven by startups located in states with high VC prevalence, which are best positioned to benefit from the role that patents play in facilitating access to venture capital. These findings thus suggest that by facilitating access to venture capital, patents act as catalysts that help set startups on a path to success.

The notion that patents can help alleviate information frictions in the market for entrepreneurial capital is not new; it has been advanced by legal (Long 2002; Mann 2005) and management scholars (Conti, Thursby, and Rothaermel 2013; Conti, Thursby, and Thursby 2013; Hsu and Ziedonis 2013) and is consistent with survey evidence (Hall and Ziedonis 2001; Graham and Sichelman 2010). However, questions remain about the extent to which patents have any value to startups in practice, particularly in light of concerns regarding startups' lack of financial resources to legally enforce their patents (Boldrin and Levine 2013; Chien 2013). In fact, in a 2015 letter to the U.S. Congress, 51 economists and legal scholars urge reform of the patent system, noting that "patent litigation now imposes substantial costs, particularly on small and innovative firms, and that these costs have tended overall to reduce R&D, venture capital investment, and firm startups" (Asay et al. 2015).[4]

Our paper's key contribution is to provide causal empirical evidence that patents facilitate startups' access to venture capital, thereby helping them grow into successful companies. Of course, information frictions are not the only reason why patents may facilitate access to capital. Even in a world with complete information, investors could value patents for the monopoly rights they bring. But the fact that firms facing the greatest frictions benefit the most from patents, coupled with the finding that the patenting effect does not depend on the scope of a patent's property rights, suggests that VCs' investment decisions reflect more than a mechanical response to the value of these rights.

Our paper also contributes to a growing literature analyzing the financial constraints faced by startups and, in particular, how VCs and other early-stage investors make investment decisions in an environment characterized by high information frictions and uncertainty. Prior work has

[4] Similar concerns have also been voiced by other public commentators. For instance, *The Economist* recently wrote that "Patents are protected by governments because they are held to promote innovation. But there is plenty of evidence that they do not. […] A top-to-bottom re-examination of whether patents … actually do their job, and even whether they deserve to exist, is long overdue." (*The Economist*, Aug. 8, 2015).

emphasized the importance of both screening and monitoring by VCs as key determinants of the success of venture-backed firms (Kaplan and Strömberg 2003, 2004; Sørensen 2007; Chemmanur, Krishnan, and Nandy 2011; Puri and Zarutskie 2012; Bernstein, Giroud, and Townsend 2015). Our results suggest that patents help VCs screen companies, particularly when investing in early rounds,[5] while at the same time improving the information flow between firms and investors by alleviating entrepreneurs' fear of expropriation.

1. Institutional Setting and Data

1.1 The patent examination process

When an inventor applies for a patent at the USPTO, the Office of Initial Patent Examination (OIPE) assigns the application to an "art unit" for review based on the application's technology field.[6] Each art unit consists of several patent examiners who share a specialization in a narrowly drawn technology field. To illustrate, the examiners in art unit 1641 are in charge of examining patent applications related to "peptide or protein sequence," examiners in art unit 2831 are in charge of applications related to "electrical connectors," examiners in art unit 3676 are in charge of applications related to "wells and earth boring," and so on. Over our sample period, the USPTO employed some 13,000 examiners in over 900 art units. The median art unit has 13 examiners; the largest more than 100.

Each application in an art unit's holding queue is assigned to one of the unit's examiners, who is responsible for assessing whether the claims in the application meet the legal thresholds of novelty, usefulness, and non-obviousness. While the details of the assignment process differ

[5] A common rule of thumb is that "for every 100 business plans that come to a venture capital firm for funding, usually only 10 or so get a serious look, and only one ends up being funded" (NVCA 2016; p. 6). Our findings indicate that patents may be one of the markers that ensure that a firm gets a "serious look."
[6] The technology field is determined through automated textual analysis of the description of the invention.

across art units,[7] one key characteristic remains constant: the assignment of applications to examiners *within a given art unit* is effectively random; in particular, it is orthogonal to the quality of the application or the applicant (Lemley and Sampat 2012; Sampat and Williams 2015). This conditional random assignment of patent applications to examiners (confirmed by our own interviews with examiners) is central to our identification strategy.

After being assigned an application, the examiner evaluates the application and makes a preliminary ruling on its validity. This ruling, called the "first-action decision," is communicated to the applicant via an official letter signed by the examiner. The median application takes 7 months to be assigned to an examiner and receives a first-action decision after an additional 10 months (i.e., approximately 1.5 years after the application date), with the final decision arriving 9 months later.[8]

Carley, Hegde, and Marco (2015) show that the first-action decision resolves substantial uncertainty about the application's ultimate fate.[9] Hence, we take the first-action date (rather than the final decision date) as our starting point for estimating how patent decisions affect firm's ability to raise capital. However, since our data do not include the content of the first-action letter (only its date), we use the final outcome of the application (approval or rejection) as a noisy proxy for the first-action decision. The data support this modeling choice: in Section 2 we show that successful applications help facilitate startups' access to VC funding within a few months of the first-action decision—that is, funding often arrives before a final decision on the

[7] For example, some units assign applications based on the last digits of the application number assigned sequentially by the OIPE, while others automatically assign the oldest application to the first available examiner.
[8] The mean lags are somewhat larger: 9 months from application to assignment, 13 months from assignment to first-action, and 14 months from first-action to final decision.
[9] Strictly speaking, patent applications are never irrevocably rejected by the USPTO; they are abandoned by applicants following what technically are appealable rejections issued by examiners (Lemley and Sampat 2008). For expositional clarity, we follow Sampat and Williams (2015) and refer to abandoned applications (i.e., the complement of those applications that are approved) as "rejected."

application has been made.[10]

1.2 Patent data and sample selection

Our patent data are drawn from the USPTO's internal databases. A key advantage of these is that they include detailed information on the review histories of both approved and rejected patent applications.[11] Until recently, publicly available datasets on U.S. patents, such as those maintained by the NBER or Harvard Business School, only covered approved patents (Lerner and Seru 2015).[12] As a result, most prior studies of the relation between patenting activity and access to capital have measured the former as stocks of *granted* patents, dated either at the time of patent application or patent grant (a prominent example is Hsu and Ziedonis (2013), who analyze the financing activities of 370 VC-funded startups in the semiconductor industry). A challenge of working with data on only granted patents is that the counterfactual for firms with patents includes both firms that applied for patents but were unsuccessful and firms that never applied for patents—either because they did not engage in innovation or because they pursued alternative mechanisms to protect their intellectual property. This can make it hard to separate the effects of investing in innovation, of choosing to patent, and of being granted a patent.

From the USPTO's internal databases, we extract data for *all* patent applications filed from 1991 onwards that have received a final decision by the end of 2013. By observing unsuccessful patent applicants, we can compare successful and unsuccessful applicants, thereby holding the patenting decision constant. At the same time, the fact that our sample is made up of firms that

[10] Measuring firm outcomes from the first-action date instead of the final decision date has an additional advantage: the final decision date for rejected applications is endogenous, as unsuccessful applicants effectively choose their final decision date by choosing when to abandon their applications.

[11] Access to the USPTO's internal databases was granted through the agency's Edison Visiting Scholars program. Carley, Hegde, and Marco (2015) provide a comprehensive description of these data.

[12] Some recent papers use publicly available data from the USPTO's Patent Application Information Retrieval (PAIR) system, which covers both approved and rejected applications filed on or after November 29, 2000. A drawback of PAIR compared to the internal databases we use is that PAIR provides no data on unsuccessful applications that opt out from public disclosure or are abandoned prior to public disclosure (around 15% of all unsuccessful applications), and no data on rejected applications before November 29, 2000.

have all applied for patents implies that our analyses are not informative about what drives the patenting decision—an important question that falls outside the scope of our study.

Our goal is to identify how the outcome of a startup's first patent application affects its ability raise venture capital and grow into a successful company.[13] The USPTO does not tag whether an applicant is a startup, so we code as startups those patent applicants that satisfy the following three filters: (1) the applicant is a U.S.-based for-profit firm which is not listed on a stock market or has been acquired by another firm by the time of the first-action decision; (2) the applicant qualifies for reduced patent fees as a small filer;[14] and (3) the applicant has filed at least one application on or after January 1, 2001 and no applications between 1991 and 2000. The first and second filters screen out universities and other non-profits, large established firms (such as listed companies and their subsidiaries), foreign applicants, and firms that no longer operate as independent companies when their first-action decision arrives. The third filter helps ensure that we capture first-time patent applicants, which are likely to be young entrepreneurial firms. In addition, we exclude from our sample those firms that have raised five or more VC rounds prior to the first-action date, as these firms are likely to have passed their startup phase. To ensure we have sufficient post-decision time to capture the effects of patent grants, we require our sample firms to receive the first-action decision on their first application by the end of 2009.

Our final sample consists of 33,855 first-time patent applicants (called startups from here on); 64.6% of them have their application approved, and the rest have it rejected. Of our sample

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[13] The firm's "first application" is the first application the USPTO rules on. (In 8% of cases, the first ruling a firm receives is not for its first-ever application but for a later application.) Identifying each firm's first application requires standardizing the assignee names in the USPTO data, to ensure that we accurately capture each firm's patenting history. Our standardization process follows Bernstein, Giroud, and Townsend (2015). In addition, we use information on firm name changes from the USPTO assignment records, supplemented with internet searches, to continue to track a startup's patenting history (as well as its capital raising history) after its name changes.

[14] A firm is eligible for reduced patent fees if (a) its number of employees, including affiliates, does not exceed 500 persons, and (b) the firm has not assigned, granted, conveyed, or licensed (and is under no obligation to do so) any rights in the invention to another firm that would not qualify for reduced patent fees (13 CFR 121.802).

firms, 31.2% operate in the electronics, computers, and communications industries; 17.8% are active in the life sciences industries; and the remaining 50.9% operate in other industries.

1.3 Venture capital and exit data

We use Thomson Reuters' VentureXpert database to identify which of our sample firms raise VC funding. In order to identify firms that go public on a major U.S. exchange (NYSE, Nasdaq, or Amex) after the first-action date, we use Thomson Reuters' SDC database and the merged Compustat/CRSP database. We also use SDC, supplemented with internet searches, to identify firms that are acquired, as well as their acquisition values when these are made public. [15] The algorithm we use to match our sample firms to VentureXpert, SDC, and Compustat/CRSP follows Bernstein, Giroud, and Townsend (2015).

1.4 Descriptive statistics

Table 1 compares startups whose first patent application is approved to those that have it rejected. Panel A shows that successful applicants are more likely to go on to raise venture capital after the first-action decision on their application: 7.5% of successful applicants go on to raise venture capital, while only 5% of unsuccessful ones do so. Successful applicants are also more likely to have a successful exit; this is true both if we measure successful exits only as IPOs (0.7% vs. 0.4%) and if we also include acquisitions at a valuation of over $25 million (2.3% vs. 1.3%). Needless to say, these differences are purely descriptive, and so no causal inferences can be drawn from them.

Panel B compares the age and size of those firms in our sample that we can match to Dun &

[15] We rely on these same databases to identify those firms that we need to filter out from our sample because they were already public or had been acquired prior to the first-action date.

Bradstreet's National Establishment Time Series (NETS).[16] Both the median successful and unsuccessful applicant are two years old. Successful applicants are slightly larger than unsuccessful ones, both in terms of employment and sales. The mean and median successful applicants have 29.2 and 8 employees, respectively, compared to 28.8 and 7 employees for their unsuccessful counterparts. For sales, the mean and median for successful applicants are $4.3 and $0.8 million, respectively, compared to $4.2 and $0.7 million for unsuccessful ones. Of course, both groups are also likely to differ along unobservable dimensions, thus underscoring the importance of addressing the endogeneity of patent grants when analyzing how patents affect access to capital.

2. First Patent Approval and Access to Venture Capital

2.1 Empirical setup and identification challenge

In order to identify how the approval of a startup's first patent application affects its ability to raise venture capital, we estimate the following equation:

$$\text{Firm raises VC funding}_{itja} = \beta \text{First patent application approved}_{itja} + \Phi X_{itja} + \varepsilon_{itja}, \tag{1}$$

where *i* indexes startups (our unit of observation), *t* application years, *j* examiners, and *a* art units. The dependent variable is an indicator set equal to one if the startup raises VC funding during some specified time interval following the USPTO's first-action decision on the firm's first patent application.

Of the startups in our sample, 92.3% have raised no VC funding before the first-action date. For these, equation (1) identifies the effect of patent approval on their ability to raise their first VC round. For firms with at least one prior VC round, equation (1) identifies the patent effect on

[16] Being privately held, the startups in our sample are not covered in standard financial databases such as Compustat, which is why we use NETS to extract information on their age, employment, and sales. We are able to match 80% of our sample firms to firms in NETS. For a quarter of the matched firms, NETS reports no sales or employment data for the year of their first patent application, typically because NETS coverage does not begin until later. We thus have sales and employment information as of the application year for 59.4% of our sample firms.

their ability to raise a follow-on round.[17] The vector *X* includes a control for the log number of prior VC rounds the firm has raised. In Section 3.2.1, we also consider sample splits based on the number of prior VC rounds raised by the firms.

One concern in estimating equation (1) is the potential for unobserved technology shocks to affect both patent applications and the supply of venture capital. For example, a breakthrough in a technology field may lead to an increase in both the number of patentable inventions and the willingness of venture capitalists to invest in startups operating in that field. To deal with this confound, we include in all analyses a full set of 2,544 art-unit-by-application-year fixed effects.[18] Since art units are quite narrowly defined (we have 475 unique art units in our sample), including these fixed effects allows us to hold technological conditions constant at a very fine level and so ensures that our findings are not confounded by unobserved industry-level shocks. Following Lerner and Seru (2015), we also control for geographic differences in financing outcomes by including firm-headquarter-state fixed effects. Standard errors are clustered at the art unit level to allow for arbitrary correlation of the errors within each art unit and, in particular, within the applications reviewed by the same examiner in any given art unit.

Ideally, *First patent application approved* would capture the outcome of the first-action decision. In practice, while the first-action decision letter resolves much uncertainty about whether the application will eventually be approved or rejected, we do not observe its content. Instead, we set *First patent application approved* equal to one if the examiner's final decision is to approve the application, and zero otherwise.[19]

[17] Specifically, 2.8% of our sample firms have raised one VC round at the time of their first-action; 2.3% have raised two VC rounds; 1.7% have raised three rounds; and the remaining 1.0% have raised four rounds.
[18] Applications belonging to art-unit-by-year singletons do not contribute to identification and so we exclude them. Including art-unit-by-year fixed effects subsumes art unit (i.e., industry) fixed effects.
[19] See footnote 21 for a discussion of how our identification strategy ensures that this data limitation does not bias our estimates.

The OLS estimate of β will likely be biased upwards, as it will capture both the average treatment effect of patents on VC fundraising and the bias induced by not controlling for ex ante differences in firm quality or access to finance. For example, a firm of higher unobserved quality at the time of filing is both more likely to have produced a "novel, useful, and non-obvious" invention worthy of a patent and to be able to raise venture capital. The ideal experiment to identify the causal contribution of a patent to a firm's ability to raise finance would randomize patent approvals, thus ensuring that successful applicants do not differ systematically from unsuccessful ones. While this ideal experiment is obviously not feasible, we can get close to it by exploiting features of the review process that induce quasi-random variation in patent approvals.

2.2 Identification strategy: Patent examiners' approval rates as IV

To identify the effect of patent grants on access to venture capital, we leverage the random assignment of applications to patent examiners within art units and exogenous variation in examiners' propensity to approve patents. Specifically, we use the examiner's past approval rate as an instrument for whether a firm's first application is approved and estimate equation (1) using two-stage least squares (2SLS). We calculate the approval rate of examiner *j* belonging to art unit *a* assigned to review firm *i*'s first patent application submitted at time *t* as follows:

$$\text{Examiner approval rate}_{ijta} = \frac{n_{\text{granted}_{jta}}}{n_{\text{reviewed}_{jta}}}, \tag{2}$$

where $n_{\text{reviewed}_{jta}}$ and $n_{\text{granted}_{jta}}$ are the numbers of patents examiner *j* has reviewed and granted *prior* to date *t*, respectively.[20, 21]

[20] Neither the numerator nor the denominator in (2) includes patent application *i*, as it had not been reviewed prior to date *t*. Also, to ensure that we measure approval rates accurately, we exclude firms whose first patent application is assigned to an examiner with fewer than 10 prior reviews. All results are robust to using alternative cutoffs.

A version of this instrument was first proposed by Sampat and Williams (2015). The instrument is also similar in spirit to the identification strategy used by a growing literature that exploits exogenous variation in how randomly assigned judges interpret the law (Kling 2006; Chang and Schoar 2013; Aizer and Doyle 2015; Dobbie and Song 2015; Galasso and Schankerman 2015; Bernstein, Colonnelli, and Iverson 2016).

2.2.1 Instrument relevance

Since patent applications are assigned to examiners quasi-randomly within an art unit, we include art-unit-by-application-year fixed effects in all regressions. Thus, for our IV to predict whether a patent application is approved, there needs to be sufficient variation within an art unit and year in the propensity of different examiners to approve applications. Previous research suggests that the patent review process leaves enough discretion in the hands of examiners for this to be the case (Lichtman 2004; Sampat and Lemley 2010; Lemley and Sampat 2012; Sampat and Williams 2015). This discretion is perhaps best illustrated by Cockburn, Kortum, and Stern (2003), who, after studying the USPTO's patent examination process in depth, conclude that "there may be as many patent offices as there are patent examiners."

Our data confirm the existence of meaningful variation in the propensity of examiners to approve patent applications. The top graph in Figure 1 shows the distribution of examiner approval rates, defined as in equation (2), in our sample. The median examiner approves 61.6% of applications, and the interquartile range is 32.9%. Part of this variation is driven by variation in approval rates across art units and time. The bottom graph in Figure 1 shows the distribution

[21] The IV is determined before the first-action decision and so addresses not only omitted-variable concerns but also potential simultaneity or reverse causality problems associated with using a patent's final outcome to proxy for the first-action decision. To illustrate the latter problems, consider a firm that raises funding between the first-action and final decisions. Such a firm could afford to spend more on lawyers to respond to concerns raised in the first-action letter, thereby increasing the likelihood of a positive final decision. Since the IV is determined before first-action, it purges the effect of unobserved actions that affect a patent's final approval probability subsequent to first-action.

of residual approval rates (obtained from a regression of approval rates on a full set of art-unit-by-application-year fixed effects). As expected, the fixed effects account for a sizable fraction of the raw variation in approval rates (the R^2 is 57.0%), but we are still left with substantial variation in residual approval rates, with an interquartile range of 17.6%.

Our approval rate estimates are based on a large number of reviewed applications per examiner: the average (median) examiner had reviewed 775 (413) applications by the time we measure her approval rate (the 10th percentile is 51). This suggests that Figure 1 reflects persistent inherent differences in examiners' propensity to approve applications and not small-sample random differences in the quality distribution of the applications they review.

Table 2 reports the first stage of our 2SLS models, that is, the results of regressing patent approval on the instrument using the following linear probability model:

$$First\ patent\ application\ approved_{itja} = \theta Examiner\ approval\ rate_{itja} + \Pi X_{itja} + u_{itja} \quad (3)$$

As required for identification, the instrument is a strong predictor of whether an application is approved. The coefficient estimate in column 1 implies that each percentage-point increase in an examiner's approval rate leads to a 0.67 percentage-point increase in the probability that a patent she reviews is approved. Thus, moving from an examiner in the 25th percentile to one in the 75th percentile in the same art unit-year would increase the approval probability by 11.8 percentage points (=0.67 × 17.6), all else equal. Not surprisingly, column 1 also shows that firms that have raised venture capital prior to the patent first-action decision are more likely to have their application approved.

The effect of an examiner's approval rate on the probability of receiving a patent is not only large economically, it is also strong statistically, with the *F* statistic well above the critical value of 10 (Stock and Yogo 2005). This ensures that our results are not subject to weak instrument bias. Column 2 shows that the first stage continues to be strong if we estimate a probit model instead of a linear probability model. The same is true if we discretize the instrument and instead of an examiner's approval rate we use as IV an indicator for whether the examiner's approval rate is above or below her art-unit-year's median (column 3).

2.2.2 Exclusion restriction

In order to satisfy the exclusion restriction, the IV must only affect VC fundraising, following the examiner's first-action decision, via the first stage (i.e., via the effect that the examiner's leniency has on the application's likelihood of approval). As noted by Angrist and Pischke (2009, p. 117), for the exclusion restriction to be satisfied, the instrument must be "as good as randomly assigned conditional on covariates." Since applications are assigned to examiners within an art unit randomly with respect to quality, once we include art-unit-by-application-year fixed effects the IV has a plausible claim to satisfying the exclusion restriction.

While the exclusion restriction is ultimately untestable, the data support the IV's validity. Table 3 shows the results of regressing the approval rate of the examiner reviewing each firm's first patent application on several pre-filing firm and application characteristics. As required by the exclusion restriction, we find no significant association between an examiner's approval rate and pre-filing VC fundraising or firm size. Nor do we find any association between our IV and the number of claims in an application, a measure of the application's scope (Merges and Nelson 1990; Lanjouw and Schankerman 2001), or the number of words in the application. (All p values in Table 7 are greater than 0.2; the large R^2s are entirely explained by the fixed effects.) Therefore, consistent with conditional random assignment of patent applications to examiners, firms whose application is assigned to a lenient examiner do not appear to differ at the time of filing from those whose application goes to a stricter examiner.[22]

While quasi-random assignment of applications to examiners is necessary for the IV to satisfy the exclusion restriction, it is not sufficient. To see why, consider the following scenario. If a startup were to learn the approval rate of its randomly assigned examiner at the time of application, it could try to predict the examiner's first-action decision based on her past review record. This prediction could then affect the startup's fundraising effort (and hence its fundraising outcomes) *before* the first-action decision. In this scenario, even a randomly assigned instrument would violate the exclusion restriction, as the examiner's approval rate would affect VC fundraising via a channel—effort before a fist-action decision on the application is made—other than the first stage. In practice, applicants are not informed of their examiner's identity until they receive the first-action letter. As a result, by the time applicants are informed of who the examiner is, it is too late to use the examiner's past record to predict her first-action decision.

2.2.3 Monotonicity

If the effect of patent grants on startups' access to capital is heterogeneous (as our evidence in Section 3.2 suggests), the validity of the IV requires, in addition to the exclusion restriction, a monotonicity assumption (Imbens and Angrist 1994): while the instrument can have no effect on some firms' likelihood of patent approval, all the firms that are affected must be affected in the same way. That is, there can be no class of patent applications whose approval likelihood (conditional on the art-unit-by-year fixed effects) systematically *decreases* when they are reviewed by a more lenient examiner. Fortunately, the fact that examiners are narrowly specialized in reviewing applications pertaining to the same technological field (as determined

[22] Ideally, we would also like to show that the ex ante quality of patent applications assigned to strict and lenient examiners is the same. Perhaps the most popular measure of patent quality is the number of citations received by the patent (Hall, Jaffe, and Trajtenberg 2005). However, this measure is not helpful for our purpose here, because approved applications are more likely to be cited than rejected ones and so citation counts are directly affected by our IV through the effect that the IV has on the application's approval likelihood.

by their art unit) makes it unlikely that certain generally lenient examiners will be systematically stricter with a particular class of applications within their narrow field.[23]

In sum, the institutional features of the USPTO review process support both the exclusion restriction and the monotonicity assumption necessary for our instrument to be valid.

2.3 Results

Table 4 reports the results of estimating equation (1) by 2SLS to capture the effect of patent decisions on a firm's ability to raise venture capital over six different time windows. Columns 1 shows that approval of a startup's first patent application causes the startup's chances of raising VC funding in the year following the first-action decision to increase by 2.3 percentage points (p=0.007). Extending the window increases the effect to 3.2, 3.5, 3.9, and 4.0 percentage points over two, three, four, and five years, respectively; the effect remains at 4.0 percentage points if we allow startups to raise venture capital at any point in the future (p<0.002 in columns 2 to 6).[24] These effects are economically large. To illustrate, the 3.5 percentage-point increase in column 3 represents a 59% increase relative to the 5.9% unconditional probability of a sample firm raising VC funding in the three years following the first-action decision.

Successful applicants tend to raise VC funding quite quickly: the median successful applicant that raises VC funding during the five-year window does so a mere 10.4 months after the first-action decision. This bunching of fundraises shortly after first-action, illustrated in Figure 2, is consistent with our hypothesis that patents play a direct causal role in facilitating startups' access to capital.

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[23] By contrast, if examiners were to, say, review both hardware and software patent applications, we would worry that some examiners might be generally lenient with hardware patents but be predisposed against software patents.
[24] For each time window, we filter out startups that do not raise VC funding but instead have a successful exit (IPO or acquisition at a valuation greater than $25 million) over that time window. This explains why the sample sizes in Table 4 decrease somewhat as we extend the time window. We study successful exits separately in Section 4.

Table 5 shows the results of estimating equation (1) using naïve OLS regressions that ignore the endogeneity of patent decisions. As expected, we find a positive and significant correlation between the approval of a startup's first patent application and its likelihood of raising venture capital (p<0.001 in all columns). Interestingly, the OLS estimates tend to be *smaller* than the 2SLS estimates (although the OLS estimates still fall within the 95% confidence interval of their 2SLS counterparts). This finding, which may appear surprising at first glance given our expectation that the OLS estimates should be upward biased, is likely a result of the fact that the IV identifies the local average treatment effect (LATE) of patents on access to capital. We defer further discussion of the differences between the OLS and 2SLS estimates until after our analysis of the heterogeneity of the patenting effect in Section 3.2, which will help us understand why the LATE and the average treatment differ.

Table 6 shows the results of analyzing the effect of patent grants using four alternative models. Columns 1-4 focus on a three-year window after the first-action decision, while columns 5-8 use a four-year window. For brevity, we do not report results for other time windows; they tend to follow a similar pattern as in Table 4, with the point estimates of the patenting effect slowly increasing as the windows expand.

Column 1 shows the results of estimating the reduced-form version of our IV, in which we directly estimate how an examiner's approval rate affects a firm's likelihood of raising venture capital. Consistent with the notion that there is a causal channel linking patent approval and access to capital, we find that firms whose first application is reviewed by a more lenient examiner are more likely to go on to raise venture capital (p=0.001).

Columns 2 and 3 show that the 2SLS results in Table 4 are robust—and if anything, the coefficient estimates become slightly larger—when we estimate two alternative versions of our

IV model. In column 2, we follow Wooldridge (2010; p. 939) and estimate a probit in the first stage; we then estimate our main equation (1) by 2SLS using the first-stage predicted probabilities to instrument for patent approval. In column 3, we use the same binary version of our IV that we used in Table 2, instrumenting patent approval with an indicator set equal to one if the examiner's approval rate is above her art-unit-year's median.

Column 4 examines whether patents' role in facilitating access to venture capital persists if we restrict our attention to high-quality VCs, defined as those with an above-median IPO rate in their past investments. The 2SLS estimate (using the same baseline IV model as in Table 4) shows that patent approval increases the likelihood of raising venture capital from a high-quality VC by 1.9 percentage points (p=0.008). This represents a 66% increase relative to the 2.9% unconditional likelihood of raising venture capital from a high-quality VC in our sample, in line with the 59% increase estimated in column 3 of Table 4 when including all VCs. Thus, both high- and low-quality VCs are more likely to invest in startups whose first patent application is approved. (All conclusions are robust to working with a four-year window in columns 5-8.)

3. How Do Patents Facilitate Access to Venture Capital?

The evidence in Section 2 indicates that the approval of a startup's first patent application leads to a sizeable increase in the startup's unconditional likelihood of raising venture capital. Our goal in this section is to enhance our understanding of how patents help alleviate startups' financing constraints by investigating the mechanisms that drive our Section 2 findings.

The entrepreneurial finance market—like any other market—is influenced by supply and demand forces. Venture capitalists are a prominent, but by no means unique, source of entrepreneurial capital; other popular financing sources include personal funds from the founder or her friends and family, angel investors, and a variety of lenders (Robb and Robinson 2014).

Entrepreneurs thus face a choice of how they want to finance their startups, and their financing preferences are likely to influence their business choices and, in particular, their patenting decisions. For instance, Conti, Thursby, and Rothaermel (2013) show that VCs value patents more than angel investors, which suggests that startups interested in raising venture capital might anticipate VCs' preferences and be more likely to patent than those targeting angel investors.[25]

Our identification strategy captures the effect of granting a first patent to firms that have all decided to patent their initial invention. The strategy thus facilitates our analysis of how patents affect financing outcomes by keeping the patenting decision constant—and thus by keeping any effect that firms' financing preferences might have on patenting also constant. This allows us to focus our analysis on the supply side of the market, and in particular on the role that patents play in alleviating information frictions in the market for entrepreneurial capital.

3.1 Patents and frictions in the entrepreneurial finance market

The entrepreneurial finance market is plagued by information frictions, which are particularly severe in the case of innovative startups trying to develop and commercialize new products or services (e.g., Evans and Jovanovic 1989; Cagetti and De Nardi 2006; Kerr and Nanda 2011). The literature has hypothesized that patents can help alleviate these frictions in at least three ways. First, a patent can reduce information asymmetry between startups and investors by helping the startup signal its quality to investors, a point emphasized by Long (2002) and Hsu and Ziedonis (2013). Indeed, Long argues that "if an easily measurable firm attribute such as patent counts is positively correlated with other less readily measurable firm attributes such as knowledge capital, then patent counts can be used as a means of conveying information about these other attributes" (p. 627).

[25] This joint determination of financing and patenting decisions is another reason why it is challenging to interpret the results of an OLS regression of financing outcomes on patent stocks.

Can a patent approval have much signaling value in light of the fact that 64.6% of the applications in our sample are approved? To answer this question, it is important to note that not all startups seeking to raise venture capital are patent applicants. A first patent grant allows a startup to distinguish itself not only from unsuccessful applicants, but also from firms that have not (yet) applied for patents. In fact, the Kauffman Firm Survey (2013) reports that only 8.8% of high-tech startups, which are those most likely to try to raise VC funding, have patents. (Among non-high-tech startups, the fraction is even lower, at 2.2%.) These patterns suggest that the approval of a startup's first patent application could allow the firm to stand out from the vast majority of startups with whom it competes for VC attention.[26]

Second, maintaining the confidentiality of their innovative ideas is a major concern for many entrepreneurs (e.g., Anton and Yao 1994, 2002; Rajan and Zingales 2001). As Biais and Perottie (2008) point out, "entrepreneurs are faced with a dilemma similar to Arrow's (1962) paradox: on the one hand, potential buyers [or investors] are not willing to pay before being told the idea and checking its value. On the other hand, they no longer need to pay for the idea once they have been told it" (p. 1106). By securing a startup's property rights on its invention, a patent can make it easier for an entrepreneur to share details of the invention with investors without fear of expropriation.[27]

Third, although not the focus of our study, Chava, Nanda, and Xiao (2015), Hochberg, Serrano, and Ziedonis (2015), and Mann (2015) argue that patents can be pledged as collateral to

[26] The fact that there is some quasi-random variation in the patent review process—which our identification strategy exploits—does not imply that patent decisions are uninformative. An examiner's mandate is to approve those applications that are novel, useful, and non-obvious; while different examiners appear to have different thresholds for these criteria, the average successful applicant is still likely to be of higher quality than the average unsuccessful one (or than the average non-applicant). This suggests that it can be rational for VCs to use patents as a screening device when selecting investments.

[27] The importance of patents when negotiating with VCs is accentuated by the fact that entrepreneurs cannot rely on non-disclosure agreements (NDAs) to protect their ideas when pitching to VCs, as most VCs refuse to sign them (Dushnitsky and Shaver 2009).

facilitate entrepreneurs' access to the debt market.

The above discussion is not meant to imply that the only potential reason why patents facilitate access to capital is by alleviating information frictions in the entrepreneurial finance market. Even in a frictionless world, patents would still have value because they give the patent owner monopoly rights on her invention. As a result, the NPV of investing in a firm with a patent will generally be higher than the NPV of investing in that same firm without the patent, and this likely helps explain why patents increase the probability of raising venture capital. Our goal in the next section is to test whether the cross-sectional variation we observe in the patenting effect is consistent with patents' role in alleviating information frictions being an important driver of this effect—but not necessarily the only driver.

3.2 Heterogeneous effects of patent grants

If the approval of a startup's first patent application facilitates access to funding by addressing information frictions in the entrepreneurial finance market, we expect this approval effect to be most beneficial to startups surrounded by the greatest frictions. Frictions are likely greatest among firms (i) trying to raise an early VC round, (ii) led by inexperienced founders, (iii) located in states with a large startup population, where attracting investors' attention is more challenging, and (iv) operating in industries in which the quality of ideas and entrepreneurs is most difficult to evaluate. By contrast, if VCs mainly value patents for the monopoly rights they confer, the patent approval effect should be strongest for patents that confer property rights with the largest scope.

The five panels in Table 7 test each of these predictions in turn. Each panel shows OLS results to the right of the 2SLS results. For brevity, we focus our discussion on the 2SLS results, while noting that, as was the case in Tables 4 and 5, the OLS estimates tend to be smaller.

3.2.1 Variation in funding round

Table 7, Panel A splits startups by the number of VC rounds raised before first-action. If early-stage startups face the greatest information frictions, we expect patent approval to be most beneficial to them. The top rows examine whether firms raise capital over the three-year window following the first-action decision, while the bottom rows show results for a four-year window.

Column 1 shows that patent approval increases the likelihood of raising the first VC round over the three years after first-action by 1.3 percentage points (p=0.078), and by 1.6 percentage points when we use a four-year window (p=0.041). These are large effects economically, representing 74% and 78% increases relative to the unconditional probabilities of raising a first VC round over three and four years (1.7% and 2.0%), respectively.

Conditional on having raised a first round, column 2 shows that patent approval increases the chances of raising a second VC round by as much as 45.5 percentage points over three years and by an almost identical 46.0 percentage points over four years (p=0.037 in both cases). These continue to be economically large increases, of almost the same size as the respective unconditional probabilities of raising a second round.

Beyond the second round, we observe a marked decline in the effect of patent approval on the likelihood of raising venture capital, both in terms of its economic magnitude relative to the unconditional fundraising probability and of its statistical significance. Column 3 shows that, for startups that have raised two prior VC rounds by the time of first-action, the patenting effect is small (representing 28% and 17% of the unconditional three- and four-year fundraising probabilities) and insignificant (p=0.645 and 0.799, respectively). These results need to be interpreted with caution, given the small sample size in column 3 and the correspondingly weak first stage. But we reach the same conclusion in column 4, where we pool all firms that have raised two and three VC rounds before first-action: the approval effect remains insignificant (p=0.145 and 0.166 over three and four years, respectively), even though the first-stage F statistics are over 10 and the standard errors are smaller than in column 2.

This pattern is what we would expect if patents alleviate information frictions by serving as easy-to-acquire signals of startup quality or by allowing early-stage entrepreneurs to credibly communicate their ideas to investors without the fear of expropriation. Indeed, by the time a startup is trying to raise a third or fourth funding round, VC investors—who typically sit on the firm's board and monitor it closely (Bernstein, Giroud, and Townsend 2015)—already have a wealth of information about the firm. As a result, the incremental information content of a patent grant should be smaller than when VCs evaluate a firm for the first or second time.[28]

3.2.2 Variation in prior entrepreneurial experience

An alternative proxy for the uncertainty surrounding a startup is the experience of its founders (Hsu and Ziedonis 2013). Table 7, Panel B tests whether the effect of patents in facilitating access to capital is stronger for startups with an inexperienced founding team. In this and the remaining panels of Table 7, we focus on the approval effect over the three years following the first-action decision to streamline our discussion and conserve space. (As noted earlier, the point estimates of the approval effect tend to slowly increase as the windows expand.)

We obtain information on prior experience from Capital IQ. Capital IQ's coverage of founders' backgrounds is most complete for firms that have raised VC funding. For this one test, we thus restrict our sample to firms that have raised at least one VC round before first-action. We are able to extract information on the founders' experience for 62% of them. Of these firms, 59%

[28] The strong approval effect we observe for firms trying to raise a second VC round is consistent with the notion that the first (or seed) round is typically small, and so VCs may not do a lot of due diligence before investing in the first round. Indeed, Ewens, Nanda and Rhodes-Kropf (2015) show that VCs increasingly follow a "spray and pray" strategy, making small seed investments in a large number of startups. Our results suggest that VCs may use patent outcomes when deciding which startups they support beyond the seed round.

have a founding team with at least one founder who previously founded a different firm, while the rest are run by teams made up exclusively of first-time entrepreneurs.

The IV results in column 1 confirm that patents facilitate access to capital the most among inexperienced founding teams. For startups with at least one experienced founder, patent approval increases the likelihood of raising follow-on VC funding by an insignificant 19.4 percentage points (p=0.312). By contrast, for teams where all founders are inexperienced, the approval effect grows to a highly significant 59.4 percentage points (p=0.010); the difference between the two effects is also significant (p=0.027).[29] These results are consistent with the notion that the role of patents in facilitating access to capital is particularly important for entrepreneurs without a founding track record that VCs can use to evaluate their quality.

3.2.3 Variation in startup agglomeration across U.S. states

Two facts combine to suggest that the value of a patent grant in obtaining VC funding varies geographically. First, VCs have a well-known preference for investing locally (Lerner 1995; Sorenson and Stuart 2001). Second, startup activity varies considerably across the country, with hotspots like California, Massachusetts, and New York being particularly popular places to start an innovative business. Combined, this implies that VCs operating in areas with larger startup populations have more potential investments to choose among than those operating in areas with fewer startups. To deal with the larger number of investments to screen, VCs may rely more on

[29] To instrument for patent approval and its interaction with inexperienced founder, our instrument set includes the examiner approval rate and its interaction with inexperienced founder. (We follow an analogous approach in the following panels in Table 7.) We do not present split-sample results for experienced and inexperienced founders because their first stage is weak ($F < 3$ in both cases).

easily observable signals such as patent grants in areas with high startup activity.[30]

Table 7, Panel C splits our sample according to whether a startup is headquartered in a state with above or below median startup agglomeration in the year of its first patent application, measured as the number of first-time patent applicants in the state. Column 1 shows that in states with high levels of startup activity, patent approval increases a startup's likelihood of raising VC funding in the next three years by 5.3 percentage points (a 65% increase relative to the unconditional likelihood; p=0.001). In states with low levels of startup activity, by contrast, the patenting effect is small and insignificant (p=0.195 in column 2). Column 3, which pools all states together, confirms that the approval effect is stronger in high startup agglomeration states (p=0.005).[31]

In fact, column 3 in Panel C shows that a startup whose first patent application is rejected is 1.8 percentage points *less* likely to raise VC funding in a high startup agglomeration state than in a state with low startup activity (p=0.034). For successful applicants, the opposite is true: successful applicants located in startup hotspots are 1.2 (=0.030 – 0.018) percentage points more likely to raise venture capital than those located in areas with low startup activity (p=0.062). While these results need to be interpreted with caution as location is chosen endogenously, they are consistent with the idea that patents play a key role in helping startups located in hubs of innovative activity stand out from the crowd.

[30] Of course, high startup agglomeration states like California and Massachusetts also concentrate a large number of venture capitalists (NVCA 2016). However, even in these high-VC-prevalence states, the VC industry is highly fragmented, as the optimal VC firm size appears to be a few hundred million in assets under management (Ewens and Rhodes-Kropf 2015). As a result, the typical VC firm in California does not have many more partners to do due diligence on investments than a VC firm in, say, Iowa, but the California VC firm is surrounded by many more startups in which it can potentially invest.

[31] Table IA.1 in the Internet Appendix shows that our conclusions are robust to excluding California from the analysis. This robustness suggests that the findings in Panel C are not be explained by the fact that non-compete agreements are not enforceable in California, and so VCs investing there may value patents as a way to ensure that the employees of their portfolio firms will not appropriate the firms' ideas to then compete against them.

3.2.4 Variation across industries

The IT (electronics, computers, and communications) and life sciences (pharmaceuticals, biotechnology, and biochemicals) industries have long been the main focus of venture capitalists in the U.S (Gompers and Lerner 2001; Graham et al. 2009). There are reasons to expect the information value of a patent to be different in these two industries. IT startups tend to be founded by younger entrepreneurs (Ewens, Nanda, and Rhodes-Kropf 2015) and their inventions often face substantial demand uncertainty. Thus, a favorable decision on an IT startup's first patent application can provide a particularly valuable early signal about the quality of its technology and its founders, while also allowing the founders to more freely discuss their idea with VCs without the fear of expropriation. Evidence from interviews at semiconductor firms suggests that the primary function of a patent in that industry is "securing capital from private investors [for firms] in the startup phase" (Hall and Ziedonis 2001).

Life sciences startups, in contrast, tend to be founded by experienced scientists, the quality of whose research can be evaluated using a variety of sources such as academic publications and National Institutes of Health grants (Li and Agha 2015). Also, VC investments in life sciences firms tend to be larger than in IT, particularly in early rounds (Ewens, Nanda, and Rhodes-Kropf 2015), and so VCs are more likely to perform extensive due diligence before investing in the life sciences. Finally, life sciences startups face relatively little demand uncertainty, with the greatest uncertainty coming from the probability of technical success and the Food and Drug Administration approval process (DiMasi 2003). These factors combined suggest that early patent decisions should reveal little incremental information about the quality of life sciences founders or the potential commercial success of their inventions.

The data support these predictions. Table 7, Panel D shows that the approval of an IT firm's first patent application increases its probability of raising VC funds in the next three years by 7.9 percentage points (p<0.001, column 1). In the life sciences, on the other hand, the approval effect is indistinguishable from zero (p=0.229, column 2), in line with our priors.[32] Column 4 shows that these estimates are significantly different from each other (p<0.001).

3.2.5 Variation in the scope of property rights

Panel E in Table 7 examines the extent to which the effect of patents in facilitating access to venture capital depends on the number of claims in the application, a measure of the scope of the patent's property rights (Merges and Nelson 1990; Lanjouw and Schankerman 2001). The larger is a patent's scope, the more valuable its property rights tend to be (Lerner 1994). Therefore, if VCs mainly value patents for the monopoly rights they confer, the patent approval effect should be strongest for patents with more claims and thus a larger scope.

The data do not support this prediction. Column 1 shows that, for patent applications whose number of claims is above their art-unit-year median, approval increases the startup's likelihood of raising VC funding in the next three years by 3.8 percentage points. This effect is almost identical to the 3.9 percentage-point increase caused by patents whose number of claims is equal to or below the median (column 2).[33] Column 3 confirms that the two increases are not significantly different from each other when we pool all applications together (p=0.399).

Taken together, the results in the five panels of Table 7 are consistent with the notion that patents' role in facilitating access to venture capital is particularly important for startups facing high information frictions and uncertainty. By contrast, the scope of a patent's property rights

[32] We caution against interpreting these findings as evidence that patents have no value to life sciences firms. What our findings indicate is that early patent decisions do not appear to be a key factor used by VCs when deciding whether to invest in life sciences firms—at least within the population of marginal quality startups whose patents' approval likelihood is affected by their examiner's leniency (see Section 3.3).

[33] There are fewer observations in column 1 than in column 2 because there are a large amount of applications whose number of claims equals their art-unit-year median, and these are included in column 2. Table IA.2 in the Internet Appendix shows that our conclusions remain unchanged—if anything, become stronger—when we balance the samples by randomly allocating applications with median number of claims to columns 1 or 2.

does not appear to be a significant driver of the patent approval effect, thus reinforcing the notion that VCs are not mechanically responding to the intrinsic value of these property rights.

That said, we emphasize that it does not follow from our findings that patents could play the same role in alleviating information frictions if they were pure quality signals carrying no property rights. In particular, patents' role in facilitating the information flow between firms and investors by alleviating entrepreneurs' fear of expropriation would not be possible without the monopoly rights associated with patents.

3.3 External validity and comparison of 2SLS and OLS estimates

When the treatment effect of the endogenous variable is heterogeneous, i.e., when its intensity varies across individuals, any IV identification strategy will identify the local average treatment effect (LATE) of the endogenous variable on the compliant subpopulation (Angrist and Pischke 2009; Imbens and Wooldridge 2009). In our context, this means that our 2SLS estimates identify how the approval of a startup's first patent application affects the likelihood of raising VC funding for the subpopulation of applicants whose approval probability is affected by their examiner's leniency. These are likely to be marginal applicants of 'medium' quality, for which being assigned a lenient or strict examiner can be the difference between approval and rejection. For non-marginal applicants, the examiner's type is unlikely to affect the outcome of the patent review: obviously good applications will be granted and obviously poor ones will be rejected.

By the same token, patents likely matter little when VCs need to decide whether to invest in a startup of obviously high or low quality. Indeed, as argued in Section 3.2, the role of patents in alleviating information frictions between startups and investors should be most important for startups surrounded by high frictions—which are likely to be both medium-quality marginal investment candidates and marginal patent applicants. This argument suggests that the LATE of patent grants on access to capital identified by our instrument will likely be larger than their average treatment effect (ATE) within the entire population of fist-time applicants. This could explain why the 2SLS estimates of the patent approval LATE tend to be larger than their naïve OLS counterparts—even if the latter are upward-biased estimates of the approval ATE.[34]

4. The Effect of Patents on the Likelihood of Going Public or Being Acquired

In this section, we analyze whether by facilitating access to venture capital, patents act as catalysts that help set startups on a path to success. Following the literature (e.g., Bernstein, Giroud, and Townsend 2015), we use two exit-based measures to capture startup success: going public or being acquired at a reported valuation of over $25 million (in year 2000 dollars).

Our 2SLS estimates in Table 8, column 1, show that a successful first-time patent application boosts the probability of an IPO by 1.0 percentage point (p=0.010), a 171% increase over the unconditional sample probability of 0.61%. The results in column 2, where we include both IPOs and high-valuation acquisitions as measures of startup success, go in the same direction: patent approval increases the probability of going public or being acquired by 2.1 percentage points (p=0.025), a 77% increase over the unconditional exit probability of 1.9%.[35]

The median successful patent applicant goes public 5.0 years after the first-action decision on its first application, while the median high-valuation acquisition takes place 4.1 years after first-action. These long lags underscore the notion that the causal link between the approval of a startup's first patent and its eventual exit is unlikely to be direct, in that IPO investors or acquirers are unlikely to directly use the application's outcome in their investment decisions. Rather, our findings in Sections 2 and 3 suggest that early patent grants act as catalysts that set

[34] See Card (2001) for an analogous discussion of why IV estimates of the returns to schooling tend to be larger than their OLS counterparts, even though OLS produces upward-biased estimates of the ATE of schooling on earnings.
[35] We observe exits through the end of 2015. Firms that have not exited by then may yet do so in the future. The art-unit-by-application-year fixed effects control for the fact that firms that applied for their first patent in the later years of our sample have had less time to exit than earlier applicants.

startups on a path to success by facilitating their access to venture capital, thereby alleviating their financial constraints.

To further establish this causal chain, Table 9 shows that the positive effect of patents on the likelihood of having a successful exit is driven by the five U.S. states with the highest VC prevalence, which have historically concentrated over two-thirds of VC activity: California, Massachusetts, New York, Texas, and Washington (NVCA 2016). Panel A focuses on IPOs while Panel B also includes exits via high-valuation acquisitions. Column 1 shows that for firms located in these five states, the approval of their first patent application increases their IPO probability by 2.9 percentage points ($p<0.001$, Panel A) and their IPO or acquisition probability by 3.9 percentage points ($p=0.004$, Panel B). By contrast, column 2 shows that, in the other 45 states, patent approval has virtually no effect on a firm's exit probability ($p=0.838$ and 0.773 in Panels A and B, respectively). Pooling all states, column 3 shows that the difference in the patent approval effect between high and low VC prevalence states is significant both when focusing on IPOs ($p=0.023$, Panel A) and when also including acquisitions ($p=0.074$, Panel B).

Given that VCs are known to invest locally, startups located in states with a large VC presence are best positioned to benefit from the role that patents play in facilitating access to venture capital. The fact that the patent approval effect on startup success is strongest for startups located in such states is consistent with the idea that the increase in the likelihood of raising venture capital induced by patent grants is a major driver of this success.

5. Conclusions

We show that the approval of a startup's first patent application increases its likelihood of raising VC funding in the following three years by 3.5 percentage points—a 59% increase relative to the unconditional probability of raising VC funding. Our findings are based on the analysis of a comprehensive sample of 33,855 first-time patent applicants exploiting as IV plausibly exogenous variation in the propensity of quasi-randomly assigned examiners to approve applications.

Patents are particularly beneficial to early-stage startups, those founded by inexperienced entrepreneurs, those located in states with a large startup population, and those operating in the IT sector. This evidence suggests that patents help mitigate information frictions between startups and investors by signaling the quality of entrepreneurs' ideas and alleviating their fear of expropriation. By doing so, patents appear to act as catalysts that help set startups on a path to success, more than doubling their unconditional IPO probability. Remarkably, this is true even though our IV identifies the patent approval effect on the subsample of ex ante marginal applicants whose approval likelihood is affected by their examiner's leniency. Our results thus underscore that the information frictions and uncertainty surrounding innovative startups are so large that even what appear to be ex ante marginal startups have the potential of becoming successful public companies.

The U.S. Congress is currently considering eight patent reform bills. Our study does not imply that the U.S. patent system is optimal, or even net-welfare enhancing, and so should not be reformed. Rather, our findings alter the balance of evidence available to those considering a revamp of the system by showing that early patents help startups overcome information frictions and finance their growth and innovation. Reforms of the patent system that do not take this role of patents into account run the risk of negatively impacting the availability of capital for innovative startups.

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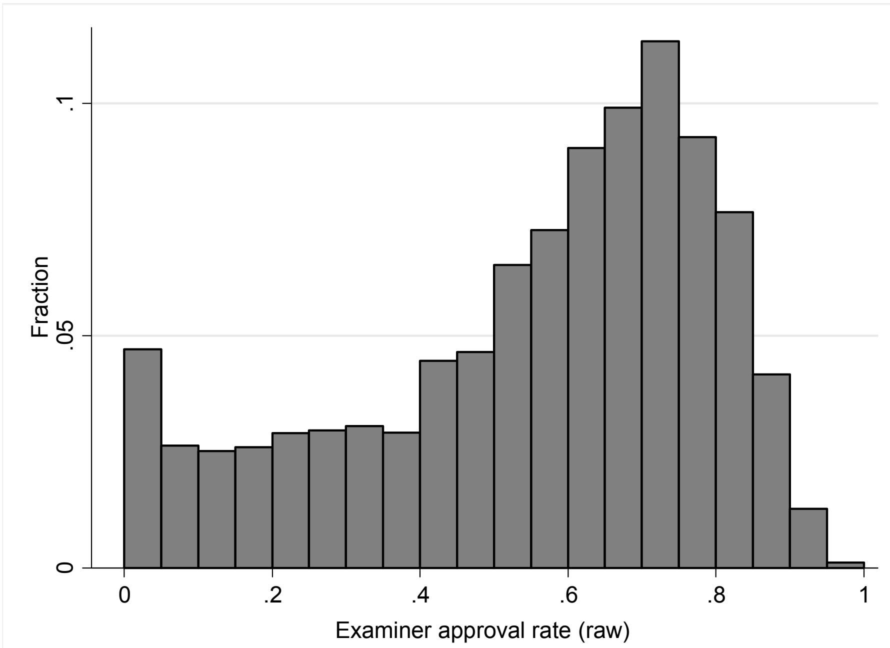
Figure 1. Distribution of Patent Examiners' Approval Rates.
Panel A shows the sample distribution of patent examiner approval rates, defined as in equation (2). Panel B shows the distribution of residual approval rates, obtained from a regression of approval rates on a full set of art-unit-by-application-year fixed effects.

Panel A. Raw approval rates.



Panel B. Residual approval rates.

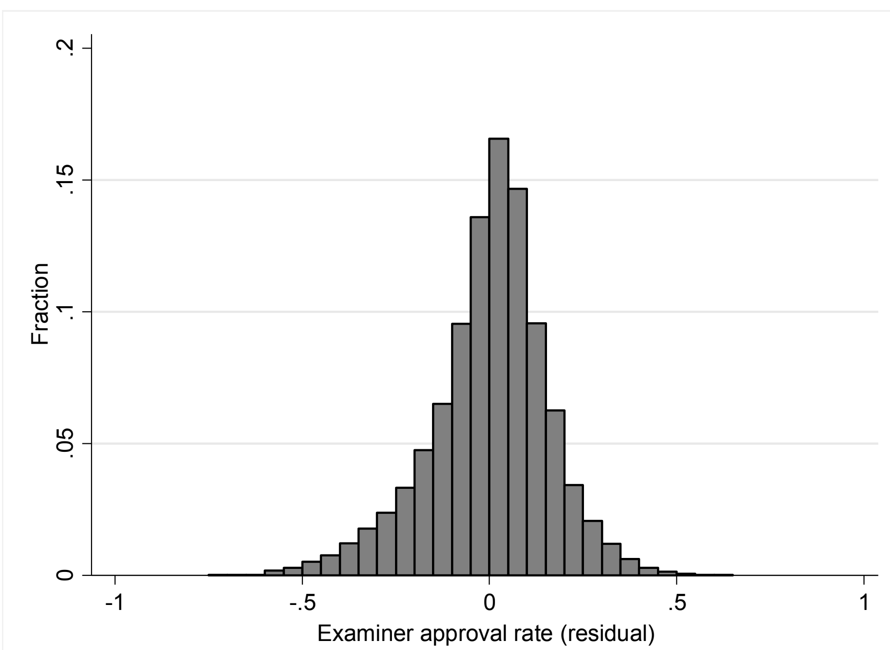


Figure 2. Time Lag Between Patent Decisions and VC Investments.
For successful first-time patent applicants that go on to raise VC funding at some point in the five years following the first-action decision, the figure shows the distribution of the time lag (in months) between the first-action date and the VC investment date.

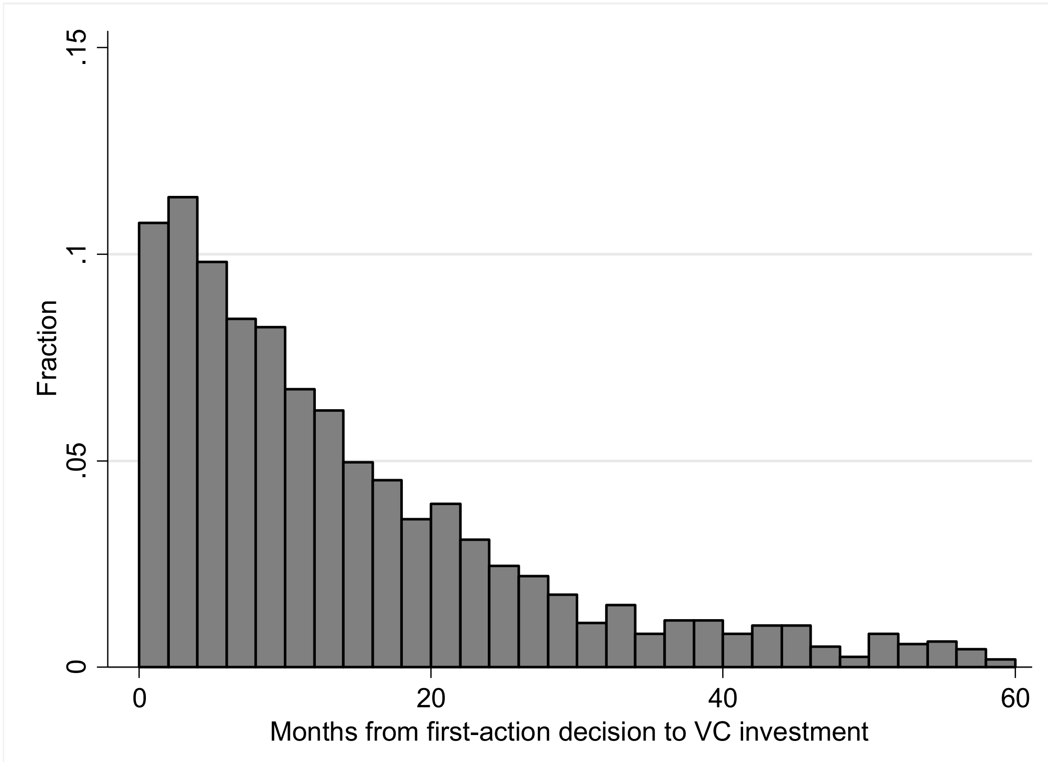


Table 1. Summary Statistics.

The table reports summary statistics for the firms in our sample of first-time patent applicants (or "startups") , broken down by whether their first application is approved or rejected. Data on employment and sales are only available for the 20,104 startups that can be matched to the National Establishment Times Series (NETS) database and for which NETS reports this information for the year of their first patent application. Data on age are available for an additional 6,818 startups that can also be matched to NETS but for which NETS does not report employment or sales information for the year of their first patent application.

		Startups whose first patent application is …	
		approved	rejected
No. startups		21,887	11,968
% of startups		64.65%	35.35%
Panel A. Subsequent VC funding, IPOs, and acquisitions			
% of startups that raise VC funding after first-action		7.53%	5.02%
% of startups that go public after first-action		0.72%	0.41%
% of startups that go public or are acquired after first-action		2.27%	1.35%
Panel B. Pre-filing characteristics (subsample matched to NETS)			
Age at first patent filing (years)	median	2	2
Employees at first patent filing date	mean	29.2	28.8
	median	8	7
	st.dev.	*61.8*	*61.3*
Sales at first patent filing date (2001 $ million)	mean	4.27	4.23
	median	0.83	0.72
	st.dev.	*9.87*	*9.99*

Table 2. Patent Examiner Approval Rate as IV: First-stage Results.

The table reports the results of estimating the first-stage equation (3) of our 2SLS analysis of how the approval of a startup's first patent application affects its ability to raise VC funding. The first stage uses the past approval rate of the patent examiner in charge of reviewing a startup's first patent application to predict whether the application will be approved. Column 1 estimates equation (3) using a linear probability model, while column 2 estimates a probit model. Column 3 uses a binary version of the instrument instead of the actual examiner's past approval rate; specifically, it estimates a linear probability model using as IV an indicator for whether the examiner's past approval rate is above or below the median past approval rate in her art-unit-year. All specifications include art-unit-by-year and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Dep. var.:	First patent application approved?		
	OLS (1)	Probit (2)	OLS (3)
IV: Patent examiner past approval rate	0.672***	0.759***	
	0.018	*0.021*	
Binary IV: Examiner w/ above median approval rate			0.155***
			0.006
Log (1 + no. prior VC rounds)	0.033***	0.043***	0.032***
	0.010	*0.012*	*0.010*
Art unit × year fixed effects	Yes	Yes	Yes
HQ state fixed effects	Yes	Yes	Yes
Diagnostics			
F test: IV (examiner past approval rate) = 0	1,367.0***	1,248.3***	567.0***
R^2 or pseudo R^2	25.6%	18.4%	23.2%
No. of observations (firms)	33,855	32,123	33,855

Table 3. Exclusion Restriction.

The table shows the results of regressing the approval rate of the examiner reviewing each firm's first patent application on several pre-filing firm and application characteristics. Columns 2 and 3 are estimated using the sample of 20,104 startups that can be matched to NETS and for which NETS reports sales and employment for the year of their first patent application. Columns 4 and 5 are estimated using the sample of 28,772 startups for which the number of claims and the number of words in their first patent application are available. All specifications are estimated by OLS and include art-unit-by-year and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Dep. var.:	IV: Patent examiner approval rate				
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)
Log (1 + no. VC rounds raised at filing date)	0.004				
	0.005				
Log (employees at filing date)		0.001			
		0.001			
Log (1 + sales at filing date)			0.000		
			0.001		
Log (no. of claims in application)				0.002	
				0.002	
Log (no. of words in application)					0.001
					0.002
Art unit × year fixed effects	Yes	Yes	Yes	Yes	Yes
HQ state fixed effects	Yes	Yes	Yes	Yes	Yes
Diagnostics					
R^2	57.1%	59.3%	59.3%	57.2%	57.2%
No. of observations (firms)	33,855	20,104	20,104	28,772	28,772

Table 4. Do Patents Affect Access to VC Funding? 2SLS Results.

The table reports the results of estimating equation (1) to examine how the approval of a startup's first patent application affects the startup's ability to raise VC funding. The dependent variable in columns 1-5 is an indicator set equal to one if the startup raises VC funding at some point in the 1…5 years following the first-action decision, respectively; the dependent variable in column 6 is an indicator set equal to one if the startup raises VC funding at any point after first-action. Startups that do not raise VC funding but instead go public over each respective time window are excluded. (Results are robust to not excluding these observations.) All specifications are estimated by 2SLS and include art-unit-by-year and headquarter-state fixed effects. We use the past approval rate of the examiner reviewing each patent application as an instrument for the likelihood that the application is approved. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

	Following the first-action decision on its first patent application, does the startup raise VC funding …					
Dep. var.:	in the next 1 year?	in the next 2 years?	in the next 3 years?	in the next 4 years?	in the next 5 years?	at any point in the future?
	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.023***	0.032***	0.035***	0.039***	0.040***	0.040***
	0.009	*0.010*	*0.010*	*0.011*	*0.011*	*0.011*
Log (1 + no. prior VC rounds)	0.309***	0.432***	0.469***	0.481***	0.485***	0.490***
	0.010	*0.010*	*0.010*	*0.011*	*0.010*	*0.010*
Diagnostics						
Mean of dep. variable	3.6%	5.3%	5.9%	6.3%	6.5%	6.7%
Median no. months from first-action to VC round for successful applicants	5.2	8.1	9.3	10.0	10.4	11.0
F test from 1st stage: IV (examiner past approval rate) = 0	1,364.2***	1,350.3***	1,342.4***	1,344.8***	1,347.2***	1,345.3***
No. of observations (firms)	33,815	33,767	33,720	33,675	33,644	33,548

Table 5. Do Patents Affect Access to VC Funding? OLS Results.

The table reports the results of estimating equation (1) by OLS instead of by 2SLS as in Table 4. The dependent variable in columns 1-5 is an indicator set equal to one if the startup raises VC funding at some point in the 1…5 years following the first-action decision, respectively; the dependent variable in column 6 is an indicator set equal to one if the startup raises VC funding at any point after first-action. Startups that do not raise VC funding but instead go public over each respective time window are excluded. (Results are robust to not excluding these observations.) All specifications are estimated by OLS and include art-unit-by-year and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

	Following the first-action decision on its first patent application, does the startup raise VC funding …					
Dep. var.:	in the next 1 year?	in the next 2 years?	in the next 3 years?	in the next 4 years?	in the next 5 years?	at any point in the future?
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)
First patent application approved	0.011***	0.018***	0.020***	0.022***	0.023***	0.024***
	0.002	*0.002*	*0.003*	*0.003*	*0.003*	*0.003*
Log (1 + no. prior VC rounds)	0.309***	0.433***	0.470***	0.482***	0.486***	0.490***
	0.010	*0.011*	*0.011*	*0.011*	*0.011*	*0.011*
Diagnostics						
Mean of dep. variable	3.6%	5.3%	5.9%	6.3%	6.5%	6.7%
Median no. months from first-action to VC round for successful applicants	5.2	8.1	9.3	10.0	10.4	11.0
R^2	35.8%	44.7%	46.9%	46.7%	46.4%	46.0%
No. of observations (firms)	33,815	33,767	33,720	33,675	33,644	33,548

Table 6. Do Patents Affect Access to VC Funding? Alternative Specifications.

The table reports the results of analyzing the effect of patent grants on access to venture capital using four alternative models to those reported in Table 4. Columns 1 and 5 shows the results of estimating the reduced-form version of our IV. In columns 2 and 6, we follow Wooldridge (2010; p. 939) and estimate a probit in the first stage; we then estimate equation (1) by 2SLS using the first-stage predicted probabilities to instrument for patent approval. In columns 3 and 7, we instrument patent approval using an indicator set equal to one if the examiner's past approval rate is above her art-unit-year's median. Columns 4 and 8 estimate the same baseline 2SLS model as in Table 4 but restrict attention to high-quality VCs. Specifically, the dependent variable in columns 4 and 8 is an indicator set equal to one if the firm raises capital from a VC that has an above-median IPO rate at the time of the investment, and zero otherwise. (When firms raise capital from more than one VC, we average their IPO rates.) All specifications include art-unit-by-year and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

	Does the startup raise VC funding in the 3 or 4 years following the first-action decision on its first patent application?							
Dep. var.:	3-year time window				4-year time window			
	Any VC			Only high quality VCs	Any VC			Only high quality VCs
	Reduced form (OLS)	IV-2SLS w/ probit in 1st stage	IV-2SLS w/ binary IV	IV-2SLS	Reduced form (OLS)	IV-2SLS w/ probit in 1st stage	IV-2SLS w/ binary IV	IV-2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
First patent application approved		0.038***	0.040***	0.019***		0.042***	0.044***	0.021***
		0.010	*0.013*	*0.007*		*0.010*	*0.013*	*0.008*
IV: Examiner past approval rate	0.024***				0.026***			
	0.007				*0.008*			
Log (1 + no. prior VC rounds)	0.470***	0.467***	0.469***	0.267***	0.483***	0.479***	0.481***	0.277***
	0.011	*0.011*	*0.010*	*0.010*	*0.011*	*0.011*	*0.011*	*0.010*
Diagnostics								
Mean of dep. variable	5.9%	5.6%	5.9%	2.9%	6.3%	5.9%	6.3%	3.1%
F or χ^2 test from 1st stage: IV (examiner approval rate) = 0		1,232.2***	569.0***	1,342.4***		1,229.8***	570.0***	1,344.8***
R^2	46.8%				46.6%			
No. of observations (firms)	33,720	31,992	33,720	33,720	33,675	31,942	33,675	33,675

Table 7. Heterogeneous Effects of Patents Grants.

The table examines how the effect of a patent grant on facilitating access to VC funding varies across different types of startups. The dependent variable in all panels is an indicator set equal to one if the startup raises VC funding in the indicated time window after the first-action decision on its first patent application. (Startups that do not raise VC funding but instead have a successful exit during that window are excluded.) Panel A splits startups by the number of VC rounds raised before the first-action date. Panel B exploits variation in the founders' prior entrepreneurial experience. Data on founder experience come from Capital IQ. Capital IQ's coverage of founders' backgrounds is most complete for firms that have raised VC funding, and so Panel B restricts our sample to firms that have raised at least one VC round before first-action. Panel C splits startups according to whether they are headquartered in a state with above median startup agglomeration in the year of their first patent application. (The high-startup-agglomeration-state indicator in Panel C is thus time-varying, which is why in columns 3 and 6 it is identified in the presence of headquarter-state fixed effects. Our conclusions are robust to not including headquarter-state fixed effects.) Panel D splits startups by industry. IT startups are those whose first patent application is reviewed by an examiner belonging to an art unit in one of the following USPTO technology centers: 21 (computer architecture, software, and information security); 24 (computer networks, multiplex communication, video distribution, and security); 26 (communications); or 28 (semiconductors, electrical and optical systems and components). Life sciences startups are those whose first patent application is reviewed by one of the following technology centers: 16 (biotechnology and organic chemistry); or 17 (chemical and materials engineering). Startups belonging to other industries are those whose first patent application is reviewed by one of the following technology centers: 36 (transportation, construction, electronic commerce, agriculture, national security and license & review); or 37 (mechanical engineering, manufacturing, products). Panel E splits startups according to whether the number of claims in their first patent application is above their art-unit-year median. In Panels C and E, column 3 has more observations than columns 1 and 2 combined because there are fewer art-unit-by-year singletons in column 3 than in columns 1 and 2 (and analogously for columns 4 through 6). The left-hand side columns are estimated by 2SLS using the approval rate of the examiner reviewing each patent application as an instrument for the likelihood that the application is approved; the columns to their right report OLS results. In Panels B, C, and E, column 3 includes the interaction of the examiner approval rate with inexperienced founder, high startup agglomeration state, and application with high no. of claims, respectively, as instrument for the interacted patent approval indicator. Analogously, in Panel D, column 4 includes the interaction of the examiner approval rate with life sciences and other industries as instruments for the interacted patent approval indicators. In these cases, the *F* test we report is a Cragg-Donald weak identification test. All specifications include art-unit-by-year fixed effects and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Panel A. Variation in funding round.

	In the 3 or 4 years following the first-action decision on its first patent application, does the startup raise …							
Dep. var.:	its first VC round?	its second VC round?	its third VC round?	its third or fourth VC round?	its first VC round?	its second VC round?	its third VC round?	its third or fourth VC round?
	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	3-year time window							
First patent application approved	0.013*	0.455**	0.130	0.264	0.009***	0.199**	0.147	0.149**
	0.007	*0.218*	*0.281*	*0.181*	*0.002*	*0.092*	*0.132*	*0.061*
Log (1 + no. prior VC rounds)				0.425**				0.401*
				0.166				*0.229*
Diagnostics								
Mean of dep. variable	1.7%	46.8%	58.8%	61.8%	1.7%	46.8%	58.8%	61.8%
F test from 1st stage:								
IV (examiner approval rate) = 0	1,162.2***	11.0***	3.0*	11.7***				
R^2					13.0%	59.9%	58.1%	50.4%
No. of observations (firms)	31,057	415	294	735	31,057	415	294	735
	4-year time window							
First patent application approved	0.016**	0.460**	0.080	0.246	0.009***	0.221**	0.208	0.172***
	0.008	*0.220*	*0.315*	*0.177*	*0.002*	*0.091*	*0.143*	*0.062*
Log (1 + no. prior VC rounds)				0.259				0.243
				0.166				*0.227*
Diagnostics								
Mean of dep. variable	2.0%	48.4%	60.8%	63.8%	2.0%	48.4%	60.8%	63.8%
F test from 1st stage:								
IV (examiner approval rate) = 0	1,162.7***	11.0***	2.8*	11.9***				
R^2					12.7%	60.3%	58.5%	51.7%
No. of observations (firms)	31,026	413	288	729	31,026	413	288	729

Panel B. Variation in entrepreneurial experience.

Dep. var.:	Does the startup raise VC funding in the 3 years following the first-action decision on its first patent application?	
	IV-2SLS	OLS
	(1)	(2)
First patent application approved	0.194	0.159**
	0.192	*0.075*
… × inexperienced founder	0.400**	0.053
	0.181	*0.118*
Inexperienced founder	-0.348***	-0.122
	0.125	*0.093*
Log (1 + no. prior VC rounds)	0.209***	0.188**
	0.064	*0.079*
Diagnostics		
Mean of dep. variable	61.4%	61.4%
F test from 1st stage	15.5***	
R^2		54.3%
No. of observations (firms)	933	933

Panel C. Variation in startup agglomeration across U.S. states.

Dep. var.:	Does the startup raise VC funding in the 3 years following the first-action decision on its first patent application?					
	High startup agglomeration states	Low startup agglomeration states	All states	High startup agglomeration states	Low startup agglomeration states	All states
	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.053***	0.015	0.020*	0.026***	0.010***	0.013***
	0.016	*0.011*	*0.011*	*0.004*	*0.003*	*0.003*
… x high startup agglomeration state			0.030***			0.015***
			0.011			*0.004*
High startup agglomeration state			-0.018**			-0.008
			0.008			*0.006*
Log(1 + no. of prior VC rounds)	0.492***	0.437***	0.469***	0.493***	0.437***	0.470***
	0.012	*0.017*	*0.010*	*0.013*	*0.018*	*0.011*
Diagnostics						
Mean of dep. variable	8.2%	3.6%	5.9%	8.2%	3.6%	5.9%
F test from 1st stage	624.4***	716.3***	1,042.7***			
R^2				52.5%	44.0%	46.9%
No. of observations (firms)	16,189	16,797	33,720	16,189	16,797	33,720

Panel D. Variation across industries.

Dep. var.:	Does the startup raise VC funding in the 3 years following the first-action decision on its first patent application?							
	IT	Life sciences	Other industries	All industries	IT	Life sciences	Other industries	All industries
	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
First patent application approved	0.079***	-0.032	0.032***	0.079***	0.038***	0.013***	0.013***	0.038***
	0.021	*0.026*	*0.012*	*0.021*	*0.006*	*0.003*	*0.003*	*0.006*
… x life sciences				-0.111***				-0.025***
				0.033				*0.008*
… x other industries				-0.047*				-0.025***
				0.024				*0.006*
Log(1 + no. of prior VC rounds)	0.452***	0.518***	0.466***	0.468***	0.454***	0.466***	0.478***	0.469***
	0.015	*0.021*	*0.020*	*0.011*	*0.016*	*0.020*	*0.022*	*0.011*
Diagnostics								
Mean of dep. variable	10.0%	7.0%	3.1%	5.9%	10.0%	7.0%	3.1%	5.9%
F test from 1st stage	526.7***	282.0***	592.9***	645.1***				
R^2					49.2%	50.1%	37.8%	46.9%
No. of observations (firms)	10,508	6,007	17,205	33,720	10,508	6,007	17,205	33,720

Panel E. Variation in the number of initial claims.

Dep. var.:	Does the startup raise VC funding in the 3 years following the first-action decision on its first patent application?					
	Applications w/ high no. of claims	Applications w/ low no. of claims	All applications	Applications w/ high no. of claims	Applications w/ low no. of claims	All applications
	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.038**	0.039***	0.037***	0.022***	0.022***	0.022***
	0.019	*0.012*	*0.011*	*0.006*	*0.003*	*0.003*
… x application with high no. of claims			0.011			0.001
			0.014			*0.005*
Application with high no. of claims			-0.003			0.004
			0.009			*0.004*
Log(1 + no. of prior VC rounds)	0.454***	0.455***	0.460***	0.454***	0.455***	0.460***
	0.016	*0.014*	*0.011*	*0.018*	*0.015*	*0.012*
Diagnostics						
Mean of dep. variable	7.2%	5.2%	6.1%	7.2%	5.2%	6.1%
F test from 1st stage	420.8***	764.7***	884.5***			
R^2				53.5%	48.1%	46.4%
No. of observations (firms)	9,255	18,392	28,574	9,255	18,392	28,574

Table 8. Do Patent Grants Affect Future Exits?

The table analyzes how the approval of a startup's first patent application affects the startup's likelihood of having a successful exit. The dependent variable in columns 1 and 3 is an indicator set equal to one if the startup goes public after the first-action decision on its first patent application, and zero otherwise. The dependent variable in columns 2 and 4 is an indicator set equal to one if the startup goes public or is acquired at a reported valuation of over $25 million (in year 2000 dollars) after first-action. Columns 1 and 2 are estimated by 2SLS using the past approval rate of the examiner reviewing each patent application as an instrument for the likelihood that the application is approved. Columns 3 and 4 are estimated by OLS. All specifications include art-unit-by-year and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Dep. var.:	Firm goes public?	Firm goes public or is acquired?	Firm goes public?	Firm goes public or is acquired?
	IV-2SLS	IV-2SLS	OLS	OLS
	(1)	(2)	(3)	(4)
First patent application approved	0.010***	0.015**	0.003***	0.009***
	0.004	*0.007*	*0.001*	*0.002*
Log(1 + no. of prior VC rounds)	0.044***	0.112***	0.044***	0.112***
	0.005	*0.007*	*0.005*	*0.008*
Diagnostics				
Mean of dep. variable	0.61%	1.94%	0.67%	2.10%
Median no. years from first-action to exit for successful applicants	5.0	4.2	5.0	4.2
F test from 1st stage: IV (examiner past approval rate) = 0	1,367.0***	1,367.0***		
R^2			14.5%	17.5%
No. of observations (firms)	33,855	33,855	33,855	33,855

Table 9. State-Level Variation in the Relationship Between Patent Grants and Future Exits.
The table analyzes how the patent approval effect on the likelihood that a startup has a successful exit depends on the level of venture capital activity in the startup's headquarter state. We classify the five U.S. states with the highest VC prevalence, California, Massachusetts, New York, Texas, and Washington, as high VC prevalence states (NVCA 2016). The remaining 45 states and D.C. are classified as low VC prevalence states. The dependent variable in Panel A is an indicator set equal to one if the startup goes public after the first-action decision on its first patent application, and zero otherwise . The dependent variable in Panel B is an indicator set equal to one if the startup goes public or is acquired at a reported valuation of over $25 million (in year 2000 dollars) after first-action. Columns 1 through 3 are estimated by 2SLS using the past approval rate of the examiner reviewing each patent application as an instrument for the likelihood that the application is approved. Column 3 includes the interaction of the examiner approval rate with the high-VC-prevalence-state indicator as instrument for the interacted patent approval indicator; in this case, the *F* test we report is a Cragg-Donald weak identification test. Columns 4 through 6 are estimated by OLS. All specifications include art-unit-by-year and headquarter-state fixed effects (the headquarter-state fixed effects preclude us from including a high-VC-prevalence-state indicator in columns 3 and 6). Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Panel A. IPOs.

Dep. var.:	Does the startup go public?					
	High VC prevalence states	Low VC prevalence states	All states	High VC prevalence states	Low VC prevalence states	All states
	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.029***	-0.001	0.006	0.007***	0.001	0.001
	0.008	*0.003*	*0.004*	*0.002*	*0.001*	*0.001*
… x high VC prevalence state			0.011**			0.005**
			0.005			*0.002*
Log(1 + no. of prior VC rounds)	0.046***	0.037***	0.044***	0.047***	0.037***	0.044***
	0.006	*0.007*	*0.005*	*0.007*	*0.007*	*0.005*
Diagnostics						
Mean of dep. variable	1.03%	0.33%	0.61%	1.03%	0.33%	0.61%
F test from 1st stage	569.1***	842.0***	1,049.7***			
R^2				23.0%	18.7%	14.5%
No. of observations (firms)	13,128	20,001	33,855	13,128	20,001	33,855

Panel B. IPOs and acquisitions.

Dep. var.:	Does the startup go public or is acquired?					
	High VC prevalence states	Low VC prevalence states	All states	High VC prevalence states	Low VC prevalence states	All states
	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.039***	0.002	0.008	0.017***	0.004**	0.005***
	0.014	*0.006*	*0.007*	*0.004*	*0.002*	*0.002*
… x high VC prevalence state			0.015*			0.011***
			0.009			*0.003*
Log(1 + no. of prior VC rounds)	0.116***	0.105***	0.112***	0.117***	0.105***	0.113***
	0.010	*0.011*	*0.007*	*0.011*	*0.012*	*0.008*
Diagnostics						
Mean of dep. variable	3.05%	1.18%	1.94%	3.05%	1.18%	1.94%
F test from 1st stage	569.1***	842.0***	1,049.7***			
R^2				25.7%	19.2%	17.6%
No. of observations (firms)	13,128	20,001	33,855	13,128	20,001	33,855

INTERNET APPENDIX

(NOT INTENDED FOR PUBLICATION)

Table IA.1. Variation in Startup Agglomeration Across U.S. States—Excluding California.

This table differs from Table 7, Panel C only in that it excludes all startups headquartered in California from the analysis (and so California startups are not included as those headquartered in high startup agglomeration states). The dependent variable is an indicator set equal to one if the startup raises VC funding in the three years following the first-action decision on its first patent application. (Startups that do not raise VC funding but instead have a successful exit in the 3 years following first-action are excluded.) All specifications include art-unit-by-year fixed effects and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Dep. var.:	Does the startup raise VC funding in the 3 years following the first-action decision on its first patent application?					
	High startup agglomeration states exc. CA	Low startup agglomeration states	All states exc. CA	High startup agglomeration states exc. CA	Low startup agglomeration states	All states exc. CA
	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.073***	0.015	0.026**	0.017***	0.010***	0.012***
	0.018	*0.011*	*0.011*	*0.005*	*0.003*	*0.003*
… x high startup agglomeration state exc. CA			0.027**			0.007
			0.012			*0.004*
High startup agglomeration state exc. CA			-0.016*			-0.003
			0.009			*0.006*
Log(1 + no. of prior VC rounds)	0.458***	0.437***	0.445***	0.460***	0.437***	0.446***
	0.019	*0.017*	*0.013*	*0.021*	*0.018*	*0.014*
Diagnostics						
Mean of dep. variable	5.0%	3.6%	4.2%	5.0%	3.6%	4.2%
F test from 1st stage	359.4***	716.3***	816.2***			
R^2				52.0%	44.0%	44.0%
No. of observations (firms)	9,085	16,797	26,627	9,085	16,797	26,627

Table IA.2. Variation in the Number of Initial Claims—Random Allocation of Applications with Median Number of Claims. This table differs from Table 7, Panel E only in the way how it treats applications with a number of claims equal to their art-unit-year's median. In Table 7, Panel E, such applications are classified as having a low number of claims (because their number of claims is not above their art-unit-year's median). In this table, they are randomly classified as having a high or low number of claims to ensure that the samples in columns 1 and 2 (and 4 and 5) are balanced. The dependent variable is an indicator set equal to one if the startup raises VC funding in the three years following the first-action decision on its first patent application. (Startups that do not raise VC funding but instead have a successful exit in the 3 years following first-action are excluded.) All specifications include art-unit-by-year fixed effects and headquarter-state fixed effects. Heteroskedasticity consistent standard errors clustered at the art unit level are shown in italics underneath the coefficient estimates. We use ***, **, and * to denote significance at the 1%, 5%, and 10% level (two-sided), respectively.

Dep. var.:	Does the startup raise VC funding in the 3 years following the first-action decision on its first patent application?					
	Applications w/ high no. of claims	Applications w/ low no. of claims	All applications	Applications w/ high no. of claims	Applications w/ low no. of claims	All applications
	IV-2SLS	IV-2SLS	IV-2SLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
First patent application approved	0.029**	0.037***	0.041***	0.021***	0.022***	0.022***
	0.015	*0.014*	*0.012*	*0.004*	*0.004*	*0.004*
… x application w/ high no. of claims			0.000			0.000
			0.012			*0.005*
Application w/ high no. of claims			0.005			0.006
			0.007			*0.004*
Log(1 + no. of prior VC rounds)	0.463***	0.450***	0.460***	0.464***	0.451***	0.460***
	0.014	*0.016*	*0.011*	*0.016*	*0.017*	*0.012*
Diagnostics						
Mean of dep. variable	6.7%	5.2%	6.1%	6.7%	5.2%	6.1%
F test from 1st stage	706.0***	600.6***	885.8***			
R^2				50.8%	50.2%	46.4%
No. of observations (firms)	13,739	13,919	28,574	13,739	13,919	28,574