Patents and Early-stage Financing: Matching versus Signalling

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Abstract

Attracting external investment is a crucial part of growing a high-technology early-stage ventures. In addition, patent is said to be an important determinant that can help startups to attract external investors. The presumption in the literature is that patents play a role of a signal of quality. However, recent evidence challenges this common view in the literature. This paper employs a novel set of data to re-examine the signalling effect of patent by studying how patents relate to the investments from angel investors and venture capitalists. Using a sample of 468 start-ups registered under the British Columbia Venture Capital Program, I find evidence against the signalling effect. Instead, the data supports a *match on financing need* selection process whereby an early-stage venture seeks out investors who have substantial funds to finance its costly patent protection R&D strategy.

Key words: Venture capital investment; angel capital investment; early-stage ventures; entrepreneurs; innovation; patents; information asymmetry; signal; selection; matching.

JEL Classification: G14, G24, O34.

1. INTRODUCTION.

Getting external financing is a crucial task for high-technology early-stage ventures. As the result, entrepreneurs spend a tremendous amount of effort to build up their companies' profiles. Among other things such as management team, R&D strategy, etc., patents are said to be an important investment criterion for early-stage financiers. According to Jack Lander, president of the United Inventors Association, vice president of the Yankee Invention Exposition and founder of the Inventor's Bookstore, investors are very impressed by patent protection. They prefer to invest in projects that offer patent protection (Pui, 2002).

However, not until recently, academic started to pay more attention into this topic. A small literature has started to look into role of patent on the financing of early-stage ventures. The common belief in the literature is that patent is a signal of quality[2]. Specifically, patents alleviates the information asymmetry problem on a startup's quality between entrepreneurs and external investors. Thus, patents increase a startup's chance of getting external financing. However, one important drawback of this literature is that our knowledge on the signalling effect of patent and, more broadly speaking, the role of patents on the financing of early stage ventures is based on a small number of papers focusing on the relationship in the venture capital market.

This paper addresses this shortage in the literature. In particular, I employ a novel set of data to shed light on two key issues: (1) how patents relate to the financing of early-stage ventures from different groups of investors and (2) what is the main mechanism that can explain the observed relationship.

[2] Long (2002) suggests that patents fit well into Spence's (1973) original conceptualization of a signal because: (i) patents are costly in terms of filing fees and information disclosure, especially for early-stage ventures (Stoney and Stoney, 2003; Williams and Berkowitz, 2001); (ii) patents are much like a certification of a novel and useful invention, which can be viewed as a proxy for quality.

The data shows several key results. First, angel investors and venture capitalists respond very differently to patents. Second, the signalling effect of patents cannot explain such difference. And finally, the data provides suggestive evidence in supporting an alternative hypothesis. I refer to this alternative hypothesis as a *match on financing need* effect of patent where by a startup that faces a greater need for external financing to support its expensive patent protection strategy targets its search for external investors who has sufficient funds to finance the startup's financing need.

As mentioned above, the role of patent to the financing of early-stage ventures has been studied in the literature. One of the pioneer work on this topic is a study conducted by Lerner in 1994, which the author reports a positive correlation between patents and venture capital investment (Lerner 1994). This positive correlation is later confirmed by few other studies (Mueller et al., 2009; Hsu & Ziedonis, 2013; Conti et al. 2013a; Conti et al. 2013b)[3]. However, not until the past decade that the literature has started to document the signalling effect of patent. For example, Mueller et al. (2009) analyse data from 190 VC-seeking German and British biotechnology companies and find that patent applications increase the likelihood of receiving venture capital financing, while patent granting decisions do not. The authors interpret these results in terms of a signalling effect since presumably patent applications carry a signal, while granting decisions do not because they are anticipated. More recently, Hsu and Ziedonis (2013) report that having larger patent application stocks increases (i) the likelihood of sourcing initial capital from prominent venture capitalists and (ii) the pre-money valuation of the early-stage venture among 370 US semiconductor companies. More importantly, these effects are stronger when a company

[3] It is important to mention that the literature on the role of innovation on VC financing is much larger. For example, Hellmann and Puri (2002) construct a dataset of companies located in the Silicon Valley to explore a similar question. The authors find that innovators, companies that are "the first to introduce new products or services", are more likely to obtain VC financing than imitators, companies that are "engaged in relatively new products and technologies but are not the first movers in their markets". Mann and Sager (2007) examine the role of patents among the pre-revenue and later-stage ventures in the software industry. The authors report that patent is significantly correlated with several measures of a company's development including number of rounds, total investment, and longevity. However, the signalling value of patents has not been examined exclusively in these studies.

(a) does not have alternative means for conveying quality to outside investors, and (b) is in the earlier stages of financing. They interpret these results in terms of signalling since the effect of patents is greater when the information asymmetry becomes greater, as one would expect in (a) and (b). Conti et al. (2013a) construct a theoretical model to study the patent choices of early-stage ventures. Their model predicts that entrepreneurs apply for more patents in situations of information asymmetry – signalling effect of patent. The authors find empirical support for their theoretical result from a sample of 787 early-stage ventures in Israel. In particular, their data shows a positive correlation between the number of new venture capital investors and the change in the number of patents between two financing rounds. This positive result is unchanged when the authors combine a small number of new angel investors with the number of venture capital investors. Similarly, Conti et al. (2013b) construct a theoretical model in which startup can send multiple signals to a heterogeneous groups of investors. Their model predicts a unique separating equilibrium in which early-stage ventures send different signal to groups of investors who value such signal the most. This theoretical prediction is is supported by the data from 117 start-ups registered with the ATDC, a technology incubator sponsored by the Georgia Institute of Technology. In particular, they find that patent, as a signal of quality, matters only to venture capital investors and angel investors seem to show interest in family and friends investment which is a proxy for founder's commitment.

While the rest of the literature focuses on how patents relate to venture capital investment, only two studies by Conti and co-authors are the only papers that analyse the effect of patents on investments from angel investors – an important source of external finance for early-stage ventures. The key result here is that the authors find that angel financing is independent with a firm's patenting activity (Conti et al. 2013a, 2013b). Their findings give rise to a key question. Is patent a signal of quality? And more broadly speaking, what is the role of patents on the financing of early-stage ventures?

I employ a unique hand-collected dataset from a sample of 468 companies registered under the British Columbia Venture Capital Program to study these questions. As a first step, I re-examine the signalling effect of patents. To do this, I first investigate how patents affect different subgroups of investors, who presumably face various degree of information asymmetry. Specifically, I divide the investors into insider and outsider investors based on whether they have invested in the company prior to the current financing round or not. I also divide the investors into local and distant investors based on their proximity to the company's head office. Under the assumption that outsider and distant investors face a greater degree of information asymmetry than insider and local investors, the signalling effect of patents must be more pronounced among the outsider and distant investors. The data shows the reverse. An increase in patent applications is associated with a lesser increase in investments from outsider and distant investors than from insider and local investors. These results suggest that patents do not play a role of signal. In addition, I employ a placebo test techniques to further examine the signalling effect of patents. This technique requires a creation of a placebo variable that takes fictitious value of the actual patent variable. Effectively, this technique turns off the signalling effect, if the effect exists. Consequently, the placebo variable should not have any relation with investments. The data shows that the placebo variable continues to have a positive relation with investments. This strengthen the evidence against the signalling effect of patent.

Instead, the data supports a *match on financing need* process (or the *matching effect* of patent) where an early-stage venture adopting a costly patent protection strategy (instead of trade secrecy) as its primary R&D strategies seek out investors who have substantial funds to meet the venture's greater need of capital[4]. Specifically, the match on financing need process predicts that a venture that produces more patents due to its choice of patent protection R&D strategy will get matched with investors who have substantial funds. In my data, investors with substantial funds are venture capitalists and angel investors who invest in more than one company. Indeed, I find that patents positively correlate with these two groups of investors. At the same time, patents do not have any relation with investments from angel investors who invest in only one company as expected. Furthermore, when controlling for a venture's current and future financing need, determined by investments received in the current and subsequent financing rounds, the correlation between patents and venture capital investments becomes insignificant. Altogether, these findings suggest that the observed positive relation between patents and venture capital investment is driven by a match on financing need process whereby a venture that needs a substantial amount of funding gets matched with an investor who has substantial amount of funding.

This paper contributes to the existing literature in at least three ways: first, it extends our knowledge on how patents affect angel financing and the financing of early-stage ventures as the whole. Second, it exploits the uniqueness of the data to conduct several additional tests on the signalling effect of patents across different groups of external investors that is not practical elsewhere. Third, it proposes an alternative explanation that can consistently explain the observed difference in relations between patents and different groups of external investors.

The results found in this paper goes beyond academic curiosity. For early-stage venture, these findings are useful when it comes to match a venture's R&D strategy with its financing strategy. In particular, it might be unnecessary to pursue venture capital investment if a venture does not adopt costly R&D projects. Alternatively, if a technology requires intellectual property

[4] Essentially, early-stage ventures have two options when it comes to R&D strategy: patent protection and trade secrecy. Hall et al. (2013) provide a literature review on this topic.

protection, searching for angel financing might not be the right financing strategy. This decision can be critical to the survival and growth of a venture. At the same time, policy makers can find these findings useful for policies design purposes. For example, policy makers must take into account the natural difference among startups to design an effective policy. In particular, if the market consists mostly of startups that need to have patent protections, using scare resources, tax credit for example, to encourage angel investments is deemed to be an suboptimal policy. In such case, along with the lack of venture capital financing, a better policy is for the government to provide direct support to the startups.

This paper proceeds as follows. Section two describes the main data sources and the construction of key variables. Section three presents the results. I conclude in section four.

2. DATA AND VARIABLES.

2.1. Data sources

The primary data source for this paper is from the British Columbia Venture Capital Program (VCP)[5] – henceforth VCP dataset. This dataset contains detailed investment information related to the companies registered under the VCP. The BC Government requests detailed company information at the registration moment. This includes information on their balance sheets, profit-and-loss accounts, descriptions of their business activity, and the number of employees. For about half of the companies we also have their business plans. In many cases, companies continue to file these documents on an annual basis thereafter. For example, companies who successfully attract

[5] The VCP was launched in 1985 to encourage private equity investments in British Columbia. At the core, the program provides 30% tax credit to BC investors for investments made into early stage ventures located in British Columbia. Currently, the program consists of four different segments targeting both angels and VCs. Hellmann, Schure, and Vo (2014) describes the VCP program in details.

risk capital are required to submit so-called annual returns that contain some financial information (mainly revenues and assets), as well as employment figures.

For a substantial subset of our companies we also have their share registries. These documents are particularly important for our analysis, since they contain the complete history of company's shareholders, dating back to the date of incorporation, and listing the precise dates of when shareholders obtained their shares. As a consequence, our data contains not only the investments made with tax-credits, but also those made without tax-credits.

We augmented the VCP dataset using several additional data sources. First, we consulted several sources to classify investors into various categories. The VCP dataset contains two groups of investors: individuals and investment vehicles. While the majority of the individuals are accredited investors, and thus are considered as angel investors in this study, the investment vehicles contain a wider range of different type of investors. We use Capital IQ, VentureXpert and internet searches to classify these investment vehicles into venture capitalists, other financial parties, corporations, and smaller groups such as universities, charitable organizations, etc.[6] Secondly, we collect information on the patent activity associated with the companies in the VCP dataset. The patent data is collected from two main data sources: the Disambiguation and Co-authorship Networks of the U.S. Patent Inventor Database 1975 – 2010 [7] (Lai, et. al. 2011) and the United States Patent and Trademark Office (USPTO) website. And finally, we gathered additional data on company's performance. The performance data comes from various sources including the BC company registry; the (Canadian) Federal company registry ("Corporations Canada"); Capital

[6] Although we have information on other types of investors in the VCP dataset, this paper focuses mainly on just angel investors and venture capital investors. Hellmann et al. (2014) looks into the relationship between angels, VCs and other investors.

[7] This dataset was constructed in 2011 by a team of researchers at the Harvard University and contained information related to all US patents from 1975 to 2010 including inventors, assignees, application dates, grant dates, etc. Detailed information on this dataset can be found at: http://thedata.harvard.edu/dvn/dv/patent/faces/study/StudyPage.xhtml?studyId=70546&versionNumber=1

IQ; ThomsonOne (VentureXpert, SDC Global New Issues and SDC Mergers and Acquisitions); Bureau Van Dijk (a data provider that collects private company data – for Canada, the main source of the Bureau Van Dijk data comes from Dunn and Bradstreet); SEDAR, which contains the record of filings with the Canadian Securities Administrators of public companies and investment funds; and the Internet (using mostly Google searches).

In the end, I am able to use information on 468 companies registered under the VCP in the period from Jan 1995 to March 2009 to examine the question of interest.

2.2. Data structure and main variables.

A. Data structure.

The main set of regressions estimate the effect of patents on the investments from angels and VCs at current financing rounds. To do this, we structure the data as a quarterly panel. Within a quarter I aggregate all investment amounts into a single round. However, in practice, companies sometimes raise a round over a span of time that either crosses across two quarter boundaries, or that exceeds the length of a quarter. We adopt the following pragmatic rules regarding financing rounds and timing of these rounds. A series of investments is considered to be a single round in case an investment takes place within ninety days of a previous investment. The date of the round is then the quarter in which the first investment within the sequence took place. Consequently, a financing round is a quarter in which a company receives financing. The final sample has in total 2,178 financing rounds associated with 18,906 transactions.

B. Main Variables.

B.1. Dependent Variables.

The key dependent variable for the round-level analysis is the investment amount in the current round made by angels and VCs.

Central to the construction of this variable is the ability to identify angels and VCs among all investors in the VCP dataset. To do this, we adopt a two-step approach. First, we separate the investors into two groups: individual investors and investment vehicles. Individual investors are identified by their first and last name. Investment vehicles are the remaining ones. To ensure that no individual investor is wrongly classified as a vehicle investor, we check on all vehicle investors to see whether there is any corporate designation such as “Ltd.”, “Corp.”, etc. in the name.

Second, we perform several name-based matches with other data sources to classify the individual investors and investment vehicles into several categories. With respect to the individual investors, it is important to distinguish angels from company founders, key employees, and their families. To do this, we match the human investors in the share registry with the list of founders identified in the company’s business plan, its annual returns, other available documents and websites. We also identify non-founding managers and other key employees using the above sources. Finally, we score investors as family members of founders and key employees if they invest in the same company and share the same last name as founders[8]. By the end of the procedure, we are able to identify almost 7,000 angel investors and over 1,040 founders, key employees and their families (henceforth “founders”) in our sample.

For some of the analyses, we further subdivide the angel investors into two groups based on the number of companies that they have invested in. The first group consists of angels who throughout our entire database invest in only one company. We refer to them as Angel Single. The remaining are angels who invest in more than one company. We refer to them as Angel Multiple. The reason for using this as a separation criteria is because the number of company invested can be thought of as a proxy for financial capability. The underlying assumption is that investing in

[8] Note that, our method cannot identify those family relationships where family members have different last names with the founders’ and key employees’ last names. Moreover, our methodology does not allow us to identify founders’ friends, as there is no objective criterion for separating those out from angel investors.

only one company suggests that the individual has limited resources. In contrast, investing in more than one company suggests that the individual has a larger pool of capital. The data also supports this assumption. As shown in Panel A of Table 1, angel-multiple constitute approximately 4% of all angel investors and invest approximately 4 times more than angel-single on average.

With respect to investment vehicles, we identify an investment vehicle as a VC using name-based matching with Capital IQ and ThomsonOne (VentureXpert). Beyond that, we classify an investor as a VC if a web search reveals that (a) they declare themselves to be a VC firm, or (b) the fund is managed by a team of investment professionals. We identified a total of over 454 VC firms in the VCP dataset.

We also subdivide all angels and VC investors into two groups based on (i) the sequence of their investments within a company and on (ii) their proximity to the company's location. Regarding the first subdivision, we split angels and VCs into two groups. The first group consists of angels and VCs who make their first investments into the company. We refer them as Angel-Outsider and VC-Outsider. The remaining are angels and VCs who re-invest in the same company. They are called Angel-Insider and VC-Insider. Regarding the second subdivision, we subdivide angels and VCs into another two groups. The first group includes angels and VC investors who locate within eighty kilometer from the company's head office. We call them as Angel-Local and VC-Local. The remaining are angels and VC investors who locate outside eighty kilometer of the company's head office. They are called Angel-Distant and VC-Distant[9]. The reason for using these

[9] I take the following approach to compute the geographic distance for a unique investor – investee company pair. First, I collect investors' and companies' postal codes from the share registries, business plans and websites. I then use the 2006 Postal Code Conversion File (PCCF) provided by Statistics Canada to find the longitude and latitude corresponding to all Canadian postal codes. For some Canadian postal codes that I am not able to match with the PCCF, I use a program that enables batch geocoding by sending requests to Google Maps API to retrieve the longitude and latitude. I also do this for all non-Canadian postal codes/zip codes to obtain their corresponding longitude and latitude. I then feed the resulting longitude and latitude of investor – investee pairs to the API service of yournavigation.org, an open source routing software based on Open Street Map. yournavigation.org then returns the travel distance in kilometers of the fastest route. Note that, not all investors provide their postal codes in the

as the separation criteria is because one can think of the sequence of investment within a company and the proximity to the company's location as proxies for how much information an investor knows about this company. The underlying assumption here is that outsider and distant investors face a greater degree of information asymmetry than insider and local investors.

Upon identifying angels and VCs and their sub-categories in the VCP dataset, the investment amounts are then computed by multiplying the reported share price by the reported volume of shares purchased[10].

Panel A of Table 1 provides some descriptive statistics on the investment amount concerning financing round and investor types. There are several key observations. First the average VC investment round is much larger ($1.09M) than the average angel financing round ($0.24M) or the average investment from other investors ($0.21M). This is consistent with the general belief that venture capital investors have a sizable capital pool which allows them to invest in larger deals than angel investors. Furthermore, the data shows that a large part of the average investment amount comes from outsider investors rather than from insider investors. This is true for both angels and VCs. In addition, companies seem to get more financing from local investors with local investors invest about four times more than distant investors. This is consistent with the local-bias phenomenon discussed in the angel financing literature[11]. And finally, among the angel investors, the average Angel-Single financing round ($0.11M) is larger than the average Angel-Multiple investment round ($0.03M). However, when we consider the average financing round with the

share registries. As the result, the sums of investment from local and distant angel and VC investors are not equal to the total investment amount about angel and VC in the same round.

[10] Sometimes, the government keeps records of the investment amount instead of the share price and volume of shared purchase.

[11] Freear et al. (1992) documented that 37% of angel investments in Connecticut and Massachusetts were made into local ventures located within 80 km away from the angel's home or office, whereas angel investments made into ventures located over 480 km away from the angel's home or office constitutes 36% of all angel investments. Some other studies have shown a greater portion of local angel investments that ranges between 50% and 87% (Wetzel, 1981; Riding et al., 1993; Mason and Harrison, 1994).

average number of Angel-Single and Angel-Multiple investors in a financing round (4.88 and 0.38 respectively), the average investment amount made by an Angel-Multiple is about four time that of an Angel-Single. This is consistent with the assumption that that angels who invest in more than one company have a larger capital pool than angels who invest in only one company.

B.2. Independent Variables.

The key independent variable is the cumulative number of patent applications (or patent application stocks) prior to the current financing round. To construct this variable, we first perform a name based matching that matches our sample of VCP companies with the companies recorded in the Disambiguation and Co-authorship Networks of the U.S. Patent Inventor Database 1975 – 2010 (Lai, et. al. 2011) on two key variables: name and location. We then manually go through each matches to ensure that those matches are indeed accurate. For the remaining unmatched companies, we manually search for them on the USPTO website. We then aggregate the number of patent applications to the quarter in which the patent application is made.

The cumulative number of patent application variables are then constructed in two different ways. The cumulative number of patent application variable is the quarterly growth of patent applications over time for a company. As shown in Table 1 Panel A, our companies has an average of 0.62 cumulative number of patent applications at a particular financing round. I also construct the cumulative number of patent application – 1 year. This variable only considers patent applications that are made four quarters (one year) prior to a financing round. The average value for the cumulative number of patent application – 1 year is 0.17. This is much less than the cumulative number of patent application variable as expected because the cumulative number of patent application variable assumes the effect of patent lasts forever and the cumulative number of patent application – 1 year variables assumes the effect of patent lasts for one year only. Although, I use the cumulative number of patent application variable as the main measure of patents, as often adopted in the literature, the key results are independent of this choice.

Regarding the total number of patent applications at the end of the sample, our data shows that there are 76 companies that have applied for patents with the USPTO. On average, our companies have 0.81 patent application at the end of the sample as shown in the first column of Table 1 – Panel B. More interestingly, as shown in column 2 and 3 of the same table, companies that do not have any VC investors (Angel-Backed companies) have a much smaller number of patent applications (0.24) compared to companies that do have VC investors and no angel investors (0.99) (VC-Backed Companies). For companies that are backed by both Angel and VC investors, as shown in column 4 of Panel B, the average number of patent applications is the greatest at 2.24 per companies. This seems to suggest that companies pursue patent protection R&D strategy face a greater need for external financing than companies that do not.

Panel B of Table 1 provides descriptive statistics at the company level for several other control variables.

The first set of controls are industry dummies. We classify companies into industries by manually matching the company's business activity to an industry classification for innovative companies loosely based on NAICS codes. For most of the companies in our sample, we obtain their business activities from the business plans and registration applications. We searched the internet for the remaining companies. As shown in Panel B, most of the VCP companies are active in the hi-tech industries that include Software & IT, Biotech, Cleantech, Telecommunication and other hi-tech manufacturing and services. Altogether these industries account for almost 76% of the companies in our data. The other 24% of the companies are mainly focused on tourism or non-high-tech manufacturing, mainly for exports. These industries are eligible because they are also deemed to further the main objective of the VCP program, namely to "enhance and diversify the

BC economy”. Note that VC-Backed companies are more hi-tech oriented than Angel-Backed companies (89% vs. 68%).

The second set of controls concern the company’s location dummies. For the majority of the companies in our sample, we observe their locations from either the business plans, the registration applications, and/or annual filings. We use internet searches to find the locations of the remaining companies. As shown in Panel B, our companies are concentrated in and around Vancouver – 73% of them are located in the Greater Vancouver Regional District (GVRD). The two smaller hubs for innovative activities are Victoria (the Capital Region District of BC), and, in the East of BC, the adjacent areas of the Okanagan and the Thompson River Valley. There is no significant difference in terms of locations between VC-Backed and Angel-Backed Companies.

In some part of the analysis, I also control for whether the company exited via IPO or M&A by May of 2014. In the VCP dataset, 17% of the companies have experienced an exit event.

I also include the company’s age as a control for the company’s development. As shown in Panel B, an average company in our data is about 2.5 years old when they acquired their first external financing and about 9.4 years old at the last period that we can observe them (exit via IPO or M&A, fail, or March 2009). Note that Angel-Backed companies are younger when they first get angel financing and remain in business for a longer period than VC-Backed companies (2.34 vs. 2.92 and 9.22 vs. 8.91). This is expected as VC investors often spend more time on due diligence to learn about the potential ventures. They also tend to push the venture to exit earlier than angel investors due to performance pressures.

Other standard controls include investment amounts in the previous round, time since last financing rounds and calendar time. Table 1 summarizes information discussed in this section.

3. RESULTS.

3.1. Main Results and Robustness

I consider a company-financing round panel where I follow the sample companies from their first to their last financing rounds. The main regression models are as follows:

$$AN_{i,t} = \alpha_1 + \beta_1 P_{i,t-1} + \gamma_1 X_i + \delta_1 X_{it} + \eta_1 T_t + \varepsilon_{1,i,t} \quad (1)$$

$$VC_{i,t} = \alpha_2 + \beta_2 P_{i,t-1} + \gamma_2 X_i + \delta_2 X_{it} + \eta_2 T_t + \varepsilon_{2,Iit} \quad (2)$$

The dependent variables are the current round investment amounts that a company *i* obtains in period *t* from angels ($AN_{i,t}$) and VCs ($VC_{i,t}$). The most important independent variables are $P_{i,t-1}$, which measure the cumulative number of patent applications that company *i* applied to up to time *t*-1.

I also include several additional controls. First, X_i is the set of variables that measure all time-invariant company characteristics, namely company age at the time of the first financing round, industry (software is the omitted category) or location (Greater Vancouver Regional District – GVRD – is the omitted category). Table 3 reports these controls, but for brevity's sake they are omitted in all subsequent Tables. Second, X_{it} is a set of variables that measure all time-variant company characteristics. These include time since the first round measured non-parametrically with a complete set of dummies for each quarter (starting the counter with the quarter when the first round occurs) and time since the last round measured non-parametrically with a complete set of dummies for each quarter, (restarting the counter every time that new round occurs). This detailed set of non-parametric controls is meant to capture independent time-varying factors, allowing us to focus specifically on the relations between patent application stocks and current financing amounts from angels and VCs. I also include last round financing amounts in this set of time-variant control. This controls for the growth in financing needs that come with the general development of a company. And finally, T_t are a complete set of calendar time fixed effects measured non-parametrically with a complete set of dummies T_t for each calendar quarter. These control for any seasonal effects, any business cycles effects, or indeed any other calendar time effects that may affect the key relation of interest. I include these controls in all regression models, but for conciseness they remain unreported in the results tables. And $\varepsilon_{1,it}$ and $\varepsilon_{2,it}$ are the standard error terms for equation (1) and (2) respectively.

These equations are estimated using OLS panel regressions with robust standard errors, which is the same as clustering by company in a panel model.

Panel A of Table 2 shows the results from the estimations of the base models. The most important results concern the relation between patent applications stocks and investments from angel and VC investors in the current round. As reported in column 2, patent applications have a significant effect on how much VCs invest. A 1% increase in the number of cumulative patent applications increases VC financing by 0.408%. This finding is consistent with the previous literature on the effect of patents on VC financing. In contrast, angel financing is independent of whether a company has patent(s) or not as shown in column 1. This result is consistent with Conti et al. (2013b), where the authors also show an insignificant correlation between patent applications and angel financing. However, unlike the Conti et al. (2013b) study, the coefficient between patent applications and angel financing reported in column 1 is negative. Although it is statistically insignificant, it shows a slight evidence of angels diverting away from companies that have applied for patents. The reason could be because angel investors foresee that these companies will need substantial future (re)financing that is beyond their financial capability.

Panel B of Table 2 reports the base model under alternative specifications. As shown in this Panel, the key relationship is robust across all specifications. In particular, columns 1 and 2 report the results of the regressions where the independent variables are dummy variables indicating where a venture receives investment from angels or VCs in the current financing amount and the dependent variables are patent application dummies, indicators of whether a company have applied for patent. The results suggest that patents increase the likelihood of getting venture capital investments. However, patents do not show any relation with investments from angel investors. This is consistent with previous results reported in Table 2 Panel A.

Columns 3 and 4 regress the investments from angels and VCs on cumulative number of patent applications 1 – year, a variable that only considers patent applications one year prior to the current financing round as discussed in the data section. The underlying assumption here is that only the most recent patents matter in attracting external financing. The key result is that patents continue to show a positive correlation with venture capital investment only, the same pattern as previous results.

Columns 5 and 6 regress the baseline model within the 95th percentile of the cumulative number of patent applications. One concern is that the results might be driven by companies that have a large number of patent applications (outliers). Although the dummy-on-dummy specification as reported in columns 1 and 2 of Panel B suggests that outliers are not of serious concern, it is still worthwhile to check for potential bias due to outliers. As shown in Column 5 and 6, the data continues to show the same pattern of the relationship between patents and investments from angels and VCs[12].

And finally, Panel C of Table 2 reports the results of the base model controlling for company fixed effects. The unique dynamic feature of our dataset allows me to include company fixed effects in the regression to control for all company and founders' time-invariant characteristics.

[12] Similar patterns of the relations are found when (i) regressing the base model that includes a control for whether a company has more than 10 patent applications (ii) replacing investment amounts by number of distinct investors as independent variables.

As shown in Panel C, the data confirms previous findings on the relations between patents and investments from angels and VCs.

3.2. Is it Signal?

Section 3.1 shows a robust pattern of the relation of patents on the financing of early-stage ventures. This probes a question: why do angels and VCs react differently to patents? More importantly, can the "signalling effect" of patents consistently explain this difference? This section provide an answer to these questions.

It is natural to answer the above questions by first examining whether patents play a role of signal. I take several steps to investigate the existence of the signalling effect. First, I examine how patents affect investments from outsider and insider investors. I then examine how patents affect investments from distant and local investors. Finally, I employ a placebo test technique.

3.2.1. Outsider versus Insider Investment.

The dynamic of the VCP data allows me to separate investors into two groups at every financing round: outsider investors and insider investors. Outsider investors are those who never invested in a company prior to the current financing round. Insider investors are those who have invested in a company prior to the current financing round.

To study the effect of patents on investments from outsider and insider investors, I use the following regression models.

$$OUTSIDER\_AN_{i,t} = \alpha_3 + \beta_3 P_{i,t-1} + CONTROLS + \varepsilon_{3,i,t} \quad (3)$$

$$INSIDER\_AN_{i,t} = \alpha_4 + \beta_4 P_{i,t-1} + CONTROLS + \varepsilon_{4,i,t} \quad (4)$$

$$OUTSIDER\_VC_{i,t} = \alpha_5 + \beta_5 P_{i,t-1} + CONTROLS + \varepsilon_{5,i,t} \quad (5)$$

$$INSIDER\_VC_{i,t} = \alpha_6 + \beta_6 P_{i,t-1} + CONTROLS + \varepsilon_{6,i,t} \quad (6)$$

The dependent variables are the current investment amounts that a company *i* obtains in period *t* from outsider investors ($OUTSIDER\_AN_{i,t}$ and $OUTSIDER\_VC_{i,t}$) and from insider investors ($INSIDER\_AN_{i,t}$ and $INSIDER\_VC_{i,t}$). The most important independent variables are $P_{i,t-1}$, which measure the cumulative number of patent applications that company *i* applied to up to time *t-1*. I also include the set of controls mentioned in section 3.1.

Dividing the investors into outsider and insider investors enables me to learn about the signalling effect of patents. It is reasonable to assume that outsider investors face a greater degree of information asymmetry than insider investors. It is the case because outsider investors have less access to critical information about the venture than insider investors. Consequently, if patents are a signal of quality, such signalling effect should matter more for outsider investors than for insider investors[13] [14].

> Hypothesis 1*: if patent has a signalling effect, then patents must have a stronger impact on outsider investors than on insider investors. In other words,* $\beta_3 > \beta_4$ *or* $\beta_5 > \beta_6$.

Table 3 reports two key results. First, with respect to angel financing, hypothesis 1 suggests that the coefficient of patents on the investments from outsider angel investments, column 1, must be greater than the coefficient of patents on the investments from insider angel investors, column 3. This is clearly not the case. Both coefficients are close to zero and the z-score suggests that there is no significant difference between them. Second, with respect to VC financing, hypothesis 1 suggests that the coefficient of patents on the investments from outsider VC investors, column 2,

[13] Hoenen et al. (2014) have also used this distinction. However the authors only use investments in first and second round where first round is treated as new investment and second round is treated as insider investments. Using this distinction, the authors show that patents only have a positive impact on the first round of VC financing among biotechnology companies. This paper establishes a much more accurate distinction on the same dimension by being able to actually identify outsider and insider investments based on unique investor IDs. This distinction is also used in a much more dynamic setting (beyond 2 rounds of financing).

[14] Conti et al. (2013a) also used a similar approach in a different regression equation to examine how outsider and insider investors influence an entrepreneur's decision to apply for patent.

must be greater than the coefficient of patents on the investments from insider VC investors, column 4. This is not the case either. Table 3 shows that while patents have no significant relation with outsider VC financing, it shows a positive and significant correlation between patents and the investments from insider VCs. These results lead to a rejection of hypothesis 1 and suggests that the signalling effect of patents does not exist.

3.2.2. Distant versus Local investors.

An alternative approach to learn about the signalling effect from patents is to examine how patents affect investments from distant and local investors. One unique feature of our data is the partial availability of investors and companies' exact locations. This allows us to compute the proximity between an investor and an investee company. This information is then used to determine whether an investor is distant or local investor. Distant investors are located outside eighty kilometers of the company's head office. Local investors are located within eighty kilometers of the company's head office.

To study the effect of patents on distant and local investors, I use the following regression models.

$$DISTANT\_AN_{i,t} = \alpha_7 + \beta_7 P_{i,t-1} + CONTROLS + \varepsilon_{7,i,t} \quad (7)$$

$$LOCAL\_AN_{i,t} = \alpha_8 + \beta_8 P_{i,t-1} + CONTROLS + \varepsilon_{8,i,t} \quad (8)$$

$$DISTANT\_VC_{i,t} = \alpha_9 + \beta_9 P_{i,t-1} + CONTROLS + \varepsilon_{9,i,t} \quad (9)$$

$$LOCAL\_VC_{i,t} = \alpha_{10} + \beta_{10} P_{i,t-1} + CONTROLS + \varepsilon_{10,i,t} \quad (10)$$

The dependent variables are the current round amounts of financing that a company *i* obtains in period *t* from distant investors ($DISTANT\_AN_{i,t}$ and $DISTANT\_VC_{i,t}$) and from local investors ($LOCAL\_AN_{i,t}$ and $LOCAL\_VC_{i,t}$). The most important independent variables are $P_{i,t-1}$, which measure the cumulative number of patent applications that company *i* applied to up to time *t-1*. I also include the set of controls mentioned in section 3.1.

Dividing the investors into distant and local investors also helps to investigate the signalling effect of patents. It is reasonable to assume that distant investors face a more severe information asymmetry problem than local investors. It is because distant investors face a greater hurdle to learn about the entrepreneurs and the ventures than local investors. For example, there might be "soft information" that can only be learned through frequent face-to-face contacts, which is only possible for local investors. Consequently, if patents are a signal of quality, such signalling effect should matter more for distant investors than for local investors[15].

> Hypothesis 2: *if patent is a signal of quality, then patents must have stronger impacts on distant investors than on local investors. In other words,* $\beta_7 > \beta_8$ *or* $\beta_9 > \beta_{10}$.

Table 4 reports two key results. First, there is no significant difference between the effect of patents on distant and local angel financings as shown in columns 1 and 3. Second, patents have a stronger effect on the investments from local VC investors than on the investments from distant VC investors as shown in columns 2 and 4. Similar to the scenario with outsider and insider investors, these results also lead to a rejection of hypothesis 2. This further supports the conclusion that patents do not play a role of a signal of quality.

3.2.3. Placebo Regression.

In this section, I use a placebo test to investigate the signalling effect of patents[16]. The placebo test is an econometric technique in which a placebo variable of the main variable of interest

[15] Conti et al. (2013a) also used a similar approach in different regression equations to examine how outsider and insider investors influence an entrepreneur's decision to apply for patent.

[16] This technique has been used in other areas of entrepreneurship: social network and entrepreneurship (Nanda & Sorensen, 2010) and capital constraint and entrepreneurship (Andersen & Nielsen, 2012)

is generated. In this context, I create a series of fictitious cumulative number of patent application variables that has the following functional form:

$$P'_t = P_{t+n}$$

P'_t is the placebo variable at time t and P_{t+n} is the actual number of cumulative patent applications at time $t+n$. If n = 0, the placebo variable is exactly the same as the actual cumulative number of patent application variable. For n>0, the placebo variable takes a value of the cumulative number of patent application at time $t+n$. Note that the placebo variable shows patent applications that have not been applied for. For example, company A applied for a patent in 2008. The cumulative patent application variable is 0 in 2007. This variable becomes 1 starting in 2008 and remains 1 for all subsequent years. Suppose now that a placebo variable $P'_t = P_{t+2}$ is generated ($n = 1$). This placebo variable has the following value: 0 in 2005, 1 in 2006, and 1 in 2007 and all subsequent years.

The main purpose for this exercise is for the placebo variable to consider the signalling effect of patent applications when there (really) is not. In other words, if patents have a signalling effect, such effect only occurs at the time when a company actually applies for a patent. In the above example, a signalling effect should only occur in 2008 and not in 2006. If a signalling effect causes the relation between patents and the financing of early-stage ventures, then the placebo variable must not show any relation with the investments because there was no signal.

Effectively, I regress the following equations.

$$VC_{i,t} = \alpha_{11} + \beta_{11}P'_{i,t-1} + CONTROLS + \varepsilon_{11,i,t} \quad (11)$$

The dependent variables are the current round amounts of VC financing that a company i obtains in period t. I focus only on VC financing because patents show a significant impact on VC financing and not on angel financing and thus failing to see a relation between the placebo variables and investments from angel financing is inconclusive. The independent variables are $P'_{i,t-1}$, which measures the cumulative number of placebo patent applications that company *i* applied up to time *t*-1. The standard set of controls is also included.

> <u>Hypothesis 3</u>: *if patent plays a role of a signal of quality, then there must be no relation between the placebo variable and the financing of early-stage ventures. In other words,* $\beta_{11} = 0$.

Table 5 reports the results. Columns 1 reports the result where *t* is set to be equal to 0. Effectively, this means that the placebo variable is the actual cumulative number of patent applications. In other words, the result reported in Column 1 is identical to the baseline model. I include it here for a comparison purpose. Column 2 and 3 regress VC financing on various placebo variables that take the values of cumulative patent applications at one and two years in the future[17]. The key result here is that all placebo variables remain positively correlated with VC financing although the signalling effect is turned off.

Furthermore, I also construct placebo variables for other measures of cumulative number of patent application that consider patent applications 1 year and 2 year prior to a current financing round. This exercise is important to address a concern that the results reported in Column 1 and 2 might be driven by the fact that placebo variables are exactly the same as the actual cumulative patent application variable for later years under the implicit assumption that the effect of patent stays forever. In the above example, this means that the placebo variable and the actual cumulative patent applications are the same from year 2008 and onward. So by using placebo variables for cumulative number of patents – 1 year and cumulative number of patents – 2 year, I effectively

[17] I actually construct placebo variables that forecast the value of the cumulative patent applications at a much more detail time window ranging from half a year to up to four years in the future. The results are the same. Thus, for brevity's sake, I report only one and two years placebo variables.

address this issue. In the above example, this means that the actual cumulative number of patent application – 1 year takes the following values: 0 in 2007, 1 in 2008, 1 in 2009, 0 in 2010 and onward. And the placebo variable for this measure of cumulative number of patent application thus takes the following value: 0 in 2005, 1 in 2006, and 1 in 2007, 0 in 2008, and 0 for all subsequent years. This effectively turns off the signalling effect of patents. As shown in Column 4 to 7, the coefficients remain significant. Altogether, this rejects hypothesis 3 and suggests that signalling effect does not exist.

In summary, I take various approached including (i) examining the impacts of patents across different groups of investors who experience different degrees of information asymmetry (outsider versus insider and distant versus local) (ii) placebo test to explore whether the signalling effect can explain the observed relation between patents and angel and VC financings. I find that patents do not play a role of a signal of quality. Consequently, the "signalling effect" cannot explain why angels and VCs respond differently on patents. The next section will propose and examine other alternative mechanism.

3.3. Match on Quality or Match on Financing Needs?

In section 3.2, it is established that the signalling effect of patents cannot explain the observed relations between patents and investments from angels and VC. In this section, I examine two alternative explanations: (i) *match on quality* and (ii) *match on financing need*.

3.3.1. Match on Quality.

The notion of a match on quality is the following. A company of high quality applies for more patents. This may be because a high quality company has a more experienced management team or a more valuable technology. At the same time, these qualities attract "high-profile" external investors, i.e. VCs. In other words, unobserved company's quality may affect both the number of patent applications and the investments from a particular group of investors.

To investigate the match on quality mechanism, one would have to control for company quality in the regression[18]. Because such variable is not readily observable in the data – a general issue that plagues this area of research – I need to find a proxy for company quality. One possible candidate is the ex-post exit event (IPO or M&A). The underlying assumption is that a high quality company is more likely to exit. This has also been a common view in the literature. Consequently, I regress the following equations.

$$AN_{i,t} = \alpha_{13} + \beta_{12}P_{i,t-1} + \lambda_{12}EXIT\_DUMMY + CONTROLS + \varepsilon_{13,i,t} \quad (12)$$

$$VC_{i,t} = \alpha_{13} + \beta_{13}P_{i,t-1} + \lambda_{13}EXIT\_DUMMY + CONTROLS + \varepsilon_{13,i,t} \quad (13)$$

The dependent variables are the current investment amounts that a company *i* obtains in period *t* from angel and VC investors. The independent variables are $P_{i,t-1}$, which measures the cumulative number of patent applications that company *i* applied to up to time *t*-1. I include an EXIT_DUMMY variable which values at 1 if a company has exited by May 2014, 0 otherwise. I also include the set of controls mentioned in section 3.1.

> <u>*Hypothesis 4*</u>*: if match on quality is the main matching process, then by controlling for quality, there should be no relation between the patents and the financing of early-stage ventures. In other words,* $\beta_{12} = 0$ *or* $\beta_{13} = 0$*.*

Table 6 reports the results of panel OLS regressions. The key result here is that controlling for company quality does not change the observed pattern of the relation between patents and

[18] Company quality has been partially controlled for in the company fixed effect regression reported in columns 5 and 6 of Table 2, Panel C. Essentially, a company fixed effect effectively controls for a company's quality that does not change over time. Because it could be the case that some company's quality does change in time, a new addition of experienced members to the management team for example, an alternative control for company quality is necessary.

investments from angels and VCs found in previous sections. Specifically, patents continue to show no relation with angel financing and show a positive and significant relation with VC financing. This rejects hypothesis 4[19].

An alternative way to examine the match of quality process is to show whether patents have any relationship with quality. To do this, I fit two separate models. The first model regresses exit on the number of patent applications prior to an exit event. The second model regresses company' pre- and post-money valuation on cumulative patent applications. As shown in table Panel A and B of Table 7, patents do not show any relationship with exit or with company valuation. In other words, a high quality venture does not necessarily imply that this venture has more patents than a low quality venture. This results support the previous finding shown in Table 6.

3.3.2. Match on Financing Need.

The notion of a match on financing need process is the following. When it comes to R&D strategy, early-stage ventures have two options: patent protection and trade secrecy (see Hall et al. (2013) for a literature review on this topic). Because patenting is costly, a venture that chooses a patent protection R&D strategy needs a greater deal of resources than a venture that does not. Consequently, this venture needs to seek out investors who have substantial funds to finance its costly patent protection R&D strategy. Consequently, a company that adopts the patent protection R&D strategy has more patents and gets financing from investors who have a sizable capital pool, VCs in this context. I call this the *matching effect* of patents.

[19] Although it's inviting to conclude that quality matching does not explain the observed pattern of the relations, the coefficient on the exit dummy suspends my judgment on that conclusion. In particular, exit has a negative and significant relation with angel financing. At the same time, exit shows a positive and significant relation with VC financing. In other words, high-quality companies get less financing from angels and more financing from VCs. In other words, some sort of quality matching might occur that cannot be fully controlled for due to data limitation

To examine the match on quality process, one would have to control for a venture's financing need. One way to construct this variable is to look at a venture's financial projection, which gives a forecast of how much financing the venture will need in the future. Another way to construct this variable is to use the total investments raised in the current round and all subsequent rounds. This gives an actual measure of how much a venture receives in term of investments, which can be a reasonable proxy (or lower bound) for a venture's financing need. Because documents on financial projections are not available, I adopt the second methods to construct the financing need variable. Consequently, I regress the following equations.

$$AN\_DUMMY_{i,t} = \alpha_{13} + \beta_{14}P_{i,t-1} + \lambda_{14}FINANCING\_NEED + CONTROLS + \varepsilon_{14,i,t} \quad (14)$$

$$VC\_DUMMY_{i,t} = \alpha_{13} + \beta_{15}P_{i,t-1} + \lambda_{15}FINANCING\_NEED + CONTROLS + \varepsilon_{15,i,t} \quad (15)$$

The dependent variables are dummy variables indicating whether a venture *i* obtain investment in period *t* from angel and VC investors. I use dummy variables instead of investment amount due to collinearity issue. The independent variables are $P_{i,t-1}$, which measures the cumulative number of patent applications that company *i* applied to up to time *t*-1. I include various measures of FINANCING_NEED variable which reflects the current and the combination of current and future financing need. I also include the set of controls mentioned in section 3.1.

<u>Hypothesis 5</u>*: if match on financing need is the main matching process, then by controlling for financing need, there should be no relation between the patents and the financing of early-stage ventures. In other words,* $\beta_{14} = 0$ *or* $\beta_{15} = 0$.

Table 8 reports the results of panel OLS regressions. Column 1 and 2 report the baseline models where I replace investment amounts by dummy variables. Column 3 and 4 regress the same model but include a control for a venture's current financing needs measured by total investment amounts a venture receives in the current financing round. Note that, the coefficients on the cumulative number of patent applications remain significant but smaller in magnitude. This suggests that by controlling for current financing needs, the effect of patents on the choice of investments (receive investments from angels or VCs) becomes less important. Column 5 and 6 also include a venture's future financing need measured by total investment amounts a venture receives in the current and all subsequent financing round as observed in the data. Column 7 and 8 are similar to column 5 and 6 except that I combine the two measures of current and future financing need into just one variable. The key result is that patents are shown to have no relation with the choice of financing sources in the presence of a control for a venture's financing need. This supports hypothesis 5 and suggests that the observed pattern of the relations between patents and investments from angels and VCs is driven by a match on financing process, where a venture seeks out investors who have substantial funds to support the venture's costly patent protection R&D strategy.

In addition, I exploit the richness of the dataset on the heterogeneity among angel investors to further examine the match on financing need process. Specifically, I divide angel investors into two separate subcategories: angel-single and angel-multiple. Angel-single is an angel investor who invests in only one company in the entire dataset. Angel–multiple is an angel investor who invests in more than one company in the entire dataset. The underlying assumption here is that an angel who invests multiple companies has a larger capital pool than an angel who invests in only one company. Indeed, the data suggests that on average an investment made by angel-multiple is about 4 times larger in terms of dollar amount per company than an investment made by angel-single. Thus, I fit the following equations.

$$AN\_SINGLE_{i,t} = \alpha_{16} + \beta_{16}P_{i,t-1} + CONTROLS + \varepsilon_{16,i,t} \quad (16)$$

$$AN\_MULTIPLE_{i,t} = \alpha_{17} + \beta_{17}P_{i,t-1} + CONTROLS + \varepsilon_{17,i,t} \quad (17)$$

The dependent variables are the current investment amounts that a company *i* obtains in period *t* from angel-single and angel-multiple investors. The independent variables are $P_{i,t-1}$, which measures the cumulative number of patent applications that company *i* applied to up to time *t*-1. I also include the set of controls mentioned in section 3.1.

> <u>*Hypothesis 6*</u>*: The matching effect of patent implies that patents should not correlate with investments from angel-single and patents should correlate with investments from angel-multiple. In other words,* $\beta_{16} = 0$ *and* $\beta_{17} > 0$.

Table 9 reports two key results of panel OLS regressions. First, patents have no relation with the financing from angel-single investors. Second, patents show a positive and significant relation with the financing from angel-multiple investors. These results support hypothesis 6 and suggest that the matching effect of patent is at play. I also report the relation between patents and venture capital investment for comparison purposes.

In summary, this section explores two alternative selection processes: match on quality and match on financing need. The data shows suggestive evidence in favor of the match on financing need process where a venture gets matched with investors who have substantial fund to finance its costly patent protection R&D strategy.

4. CONCLUSION.

Recent development in the literature has documented an interesting pattern of the relations between patents and the financing of early-stage ventures. On the one hand, patents are shown to have a positive correlation with venture capital investment. At the same time, patents are reported to have no impact on angel capital investments. This pattern raises a question about the consistency of the signalling effect of patent in explaining the relations between patents and the financing of early-stage ventures, a presumption in the literature.

I use a sample of 468 early-stage ventures registered under the British Columbia Venture Capital Program to re-examine the signalling effect of patents. I find several evidence against the signalling effect of patent. First, patents have smaller effects on groups of investors where the signalling effect are supposed to matter the more because these investors face a greater degree of information asymmetry. In addition, a placebo test shows that placebo variables of patents continue to show a positive correlation with investments although the signalling effect, if exists, have been turned off. Instead, this paper proposes and supports an alternative *match on financing need* effect of patent whereby an early-stage venture seeks out investors who have substantial funds to finance the venture's costly patent protection R&D strategy.

The results found in this paper goes beyond academic curiosity. For early-stage venture, these findings are useful when it comes to match a venture's R&D strategy with its financing strategy. In particular, it might be unnecessary to pursue venture capital investment if a venture does not adopt costly R&D projects. Alternatively, if a technology requires intellectual property protection, chasing after angel financing might not be the right financing strategy. This decision can be critical to the survival and growth of a venture. At the same time, policy makers can find these findings useful for policies design purposes. In particular, policy makers should take into account the natural difference among startups when designing a policy. For example, policy that encourages angel investment in a market that contains mostly startups that need patent protection may be suboptimal. In such case, along with the permanent shortage of venture capital investment, a better policy would be for the government to provide direct support to the startups.

Readers should be cautious when interpret these findings. The relation between patents and early-stage financing is fairly complex. And clearly, it can be influenced by many characteristics that are not readily observable in the data. As data becomes more available, it is hopeful that soon one can find the "perfect" answer to this complex relation between patents and the financing of early-stage ventures. However until then, the debate between the matching and signalling effect of patents will go on.

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Table 1: Descriptive Statistics

Panel A - Descriptive Statistics of Time-Variant Variables. This table reports the average value of the specified variables at financing round level. All variables are defined in Table A1 in the Appendix.

		All	
	# Obs	Mean	SD
Investment Amount in Current Financing Round			
Angel-Single $	2178	114,000	372000
Angel-Multiple $	2178	25,000	17,000
Angel $	2178	240,000	609,000
VC $	2178	1,085,000	5,795,000
Angel-Outsider $	2178	196,000	576,000
Angel-Insider $	2178	43,000	170,000
VC-Outsider $	2178	996,000	5,692,000
VC-Insider $	2178	89,000	68,000
Angel-Distant $	2039	45,000	234,000
Angel-Local $	1654	146,000	453,000
VC-Distant $	2133	39,000	537,000
VC-Local $	1698	167,000	872,000
Number of Investors in Current Financing Round			
Angel-Single #	2178	4.88	13.09
Angel-Multiple #	2178	0.38	1.31
Angel-Patent #	2178	0.14	0.72
Angel #	2178	6.66	14.48
VC #	2178	0.93	2.27
Other #	2178	1.62	4.79
Other			
Cumulative # Patent Applications	2178	0.62	2.94
Cumulative # Patent Applications – 1 Year	2178	0.17	0.87
Current Financing Need	2178	1,534,000	6,165,000
Future Financing Need	2178	5,285,000	18,693,000
Current & Future Financing Need	2178	6,819,000	20,859,000
Pre-money Valuation	908	2,212,000	4,574,000
Post-money Valuation	908	3,394,000	6,158,000

Panel B - Descriptive Statistics of Time-Invariant Control Variables. This table reports the average value of the specified variables at the company level. All variables are defined in Table A1 in the Appendix.

Variable	All			Angel-Backed Company			VC-Backed Company			Angel & VC-Backed Company			Other-Backed Company		
	# Com.	Mean	SD	# Com.	Mean	SD	# Com.	Mean	SD	# Com.	Mean	SD	# Com.	Mean	SD
Industry															
Software & IT	468	0.28	0.45	288	0.26	0.44	69	0.35	0.48	107	0.30	0.46	4	0.25	0.50
Biotech	468	0.12	0.33	288	0.07	0.25	69	0.20	0.41	107	0.22	0.42	4	0.00	0.00
Cleantech	468	0.05	0.23	288	0.06	0.24	69	0.03	0.17	107	0.06	0.23	4	0.00	0.00
Telecommunication	468	0.07	0.26	288	0.06	0.23	69	0.09	0.28	107	0.09	0.29	4	0.25	0.50
Hi-tech Manufacturing	468	0.18	0.38	288	0.16	0.37	69	0.16	0.37	107	0.24	0.43	4	0.00	0.00
Hi-tech Services	468	0.06	0.23	288	0.07	0.25	69	0.06	0.24	107	0.02	0.14	4	0.25	0.50
Tourism, Forestry & Mining	468	0.08	0.27	288	0.12	0.32	69	0.00	0.00	107	0.01	0.10	4	0.25	0.50
Other Manufacturing & Services	468	0.16	0.37	288	0.21	0.41	69	0.12	0.32	107	0.06	0.23	4	0.00	0.00
Location															
Greater Vancouver Regional District	468	0.73	0.44	288	0.68	0.47	69	0.75	0.43	107	0.86	0.35	4	0.75	0.50
Capital Region District	468	0.07	0.26	288	0.07	0.25	69	0.10	0.30	107	0.07	0.26	4	0.00	0.00
Okanagan/Thompson Valley	468	0.05	0.22	288	0.05	0.22	69	0.07	0.26	107	0.03	0.17	4	0.25	0.50
Rest of BC	468	0.15	0.35	288	0.20	0.40	69	0.07	0.26	107	0.04	0.19	4	0.00	0.00
Other															
Number of Pat. App. at End of Sample Period (#)	468	0.81	3.93	288	0.24	0.98	69	0.99	5.84	107	2.24	6.36	4	0.00	0.00
Age at First Round (Yrs)	468	2.52	3.60	288	2.34	3.21	69	2.92	3.87	107	2.77	4.39	4	1.31	1.80
Age at End of Sample (Yrs)	468	9.41	5.71	288	9.22	5.56	69	8.91	5.90	107	10.37	5.95	4	6.19	4.98
Exit	468	0.17	0.37	288	0.08	0.27	69	0.45	0.50	107	0.23	0.42	4	0.00	0.00

Table 2: Patents and Current Financing

Panel A - Base line result.

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts of Angels and VCs. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications. The other reported independent variables are company age at the first financing round, previous round amount, region dummies, industry dummies, and the share registry dummy. The unreported control variables are three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log Investment Amount in Current Round	
	1	2
Independent Variables	Angel $	VC $
Log Prior Cumulative Number Applications	-0.117	0.408***
	(0.128)	(0.135)
Age at First Round	-0.114*	0.140*
	(0.0601)	(0.0760)
Capital Region District	0.151	0.671
	(0.916)	(1.127)
Okanagan/Thomson Valley	-0.566	0.292
	(1.019)	(1.046)
Rest of BC	1.727***	-2.347***
	(0.586)	(0.687)
Biotech	-0.103	1.534
	(0.816)	(1.011)
Cleantech	3.311***	-1.495
	(0.975)	(1.233)
IT&Telecom	-0.120	1.382
	(1.117)	(1.359)
High-tech Manufacturing	1.395*	-0.609
	(0.713)	(0.877)
High-tech Services	1.665	-2.654**
	(1.166)	(1.273)
Tourism	2.208**	-3.885***
	(1.047)	(0.650)
Other industry	2.566***	-3.090***
	(0.779)	(0.889)
Controls	YES	YES
Observations	1,710	1,710
Number of Companies	468	468
R-square	0.286	0.372

Table 2: The Relationship between Patent and Current Financing

Panel B - Robustness Check

Results of panel OLS regressions at the financing round level. The dependent variables are dummy variables indicating whether a company receives Angel or VC financing in the current round and the natural logarithm of 0.01 plus the current investment amounts from Angels and VCs. The main independent variables are the dummy variable indicating whether a company has any patent application prior to the current financing round, the natural logarithm of 0.01 plus the prior cumulative number of patent applications where the effect of patents last for only 1 year, and the natural logarithm of 0.01 plus the prior cumulative number of patent applications. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Receiving Financing in Current Round Dummy		Log Investment Amount in Current Round			
					95th Percentile	
	1	2	3	4	5	6
VARIABLES	Angel Dummy	VC Dummy	Angel $	VC $	Angel $	VC $
Patent Application Dummy	-0.0228	0.0977**				
	(0.0448)	(0.0437)				
Log Prior Cumulative Number Applications – 1 Year			0.122	0.270*		
			(0.172)	(0.152)		
Log Prior Cumulative Number Applications					-0.0451	0.302*
					(0.142)	(0.160)
Controls	YES	YES	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710	1,615	1,615
Number of Companies	468	468	468	468	460	460
R-squared	0.306	0.358	0.290	0.376	0.272	0.347

Table 2: Patents and Current Financing

Panel C - Robustness Check: Company Fixed Effect

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts from Angels and VCs. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Company Fixed Effect	
	Log Investment Amount in Current Round	
	1	2
VARIABLES	Angel $	VC $
Log Prior Cumulative Number Applications	-0.384	0.736***
	(0.235)	(0.196)
Controls	YES	YES
Observations	1,710	1,710
Number of Companies	468	468
R-squared	0.239	0.211

Table 3: Patents and Investments from Outsider and Insider Investors

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts from Outsider and Insider Angels and VCs. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log Investment Amount in Current Round			
	Outsider Investors		Insider Investors	
	1	2	3	4
VARIABLES	Angel $	VC $	Angel $	VC $
Log Prior Cumulative Number Applications	-0.0279	0.0351	-0.0311	0.654***
	(0.132)	(0.127)	(0.0976)	(0.145)
Controls	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710
Number of Companies	468	468	468	468
R-squared	0.203	0.361	0.352	0.292

Table 4: Patents and Investments from Distant and Local Investors

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts from Distant and Local Angels and VCs. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log Investment Amount in Current Round			
	Distant Investors		Local Investors	
	1	2	3	4
VARIABLES	Angel $	VC $	Angel $	VC $
Log Prior Cumulative Number Applications	-0.0739	0.199**	-0.0322	0.563***
	(0.102)	(0.0785)	(0.130)	(0.140)
Controls	YES	YES	YES	YES
Observations	1,609	1,667	1,316	1,317
Number of Companies	460	467	368	381
R-squared	0.268	0.167	0.355	0.340

Table 5: Patents on Current Financing - Placebo Regression

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts of VCs. The main independent variables are the natural logarithm of 0.01 plus the placebo number of patent applications that takes fictitious value of the actual cumulative number of patents. The effect of patents are assumed to last for an infinite time horizon (columns 1, 2, and 3), for only 1 year (columns 4 and 5), and for only 2 years (columns 6 and 7). The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log Investment Amount in Current Round						
	1	2	3	4	5	6	7
VARIABLES	VC $	VC $	VC $	VC $	VC $	VC $	VC $
Log Prior Cumulative Number Placebo Applications ($P'_t = P_t$)	0.408***						
	(0.135)						
Log Prior Cumulative Number Placebo Applications ($P'_t = P_{t+1yr}$)		0.421***					
		(0.132)					
Log Prior Cumulative Number Placebo Applications ($P'_t = P_{t+2yr}$)			0.412***				
			(0.142)				
Log Prior Cumulative Number Placebo Applications ($P''_t = P^1_{t+1}$) – 1 Year Effect				0.434***			
				(0.148)			
Log Prior Cumulative Number Placebo Applications ($P''_t = P^1_{t+2}$) – 1 Year Effect					0.407***		
					(0.135)		
Log Prior Cumulative Number Placebo Applications ($P'''_t = P^2_{t+1}$) – 2 Year Effect						0.347**	
						(0.160)	
Log Prior Cumulative Number Placebo Applications ($P'''_t = P^2_{t+2}$) – 2 Year Effect							0.388***
							(0.126)
Controls	YES	YES	YES	YES	YES	YES	YES
Observations	1,710	1,697	1,633	1,697	1,633	1,697	1,633
Number of Companies	468	456	412	456	412	456	412
R-squared	0.372	0.374	0.370	0.386	0.378	0.381	0.380

Table 6: Patents on Current Financing – Match on Quality with Exit Control.

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts from Angels and VCs. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications, Exit Dummy variable indicating whether the company has experienced an IPO or M&A at the end of the sample period. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log Investment Amount in Current Round	
	1	2
VARIABLES	Angel $	VC $
Log Prior Cumulative Number Applications	-0.135	0.438***
	(0.128)	(0.134)
Exit Dummy	-2.777***	4.758***
	(0.749)	(0.841)
Controls	YES	YES
Observations	1,710	1,710
Number of Companies	468	468
R-squared	0.302	0.404

Table 7: Patents of Current Financing – Match on Quality.

Panel A – Effect of Patent on Exit
Results of OLS regressions at the company level. The dependent variables are Exit Dummies indicating whether a company experiences an IPO or M&A at the end of the sample period. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications, the natural logarithm of 0.01 plus the prior cumulative amount of Angel financing, and the natural logarithm of 0.01 plus the prior cumulative amount of VC financing. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Exit Dummy	
VARIABLES	1	2
Log Prior Cumulative Number Applications (1)	-0.00365	-0.00770
	(0.00496)	(0.00557)
Log Prior Cumulative Angel Financing (2)		-0.00524
		(0.00358)
Log Prior Cumulative VC Financing (3)		0.00724***
		(0.00207)
Controls	YES	YES
Observations	468	468
Number of Companies	468	468
R-squared	0.530	0.563

Panel B: Patent on Company Valuation.

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current pre-money and post-money valuation. The main independent variables are the natural logarithm of 0.01 plus the prior cumulative number of patent applications and the natural logarithm of 0.01 plus the last round pre-money valuation. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Company Valuation	
	1	2
VARIABLES	Pre-Money	Pre-Money
Log Prior Cumulative Number Applications	0.0398	0.0264
	(0.0394)	(0.0367)
Log Last Round Pre-Money Valuation		0.0784***
		(0.0106)
Controls	YES	YES
Observations	677	677
Number of Companies	199	199

R-squared	0.823	0.839

Table 8: Effect of Patent on Financing - Quality Matching - Control for Financing Need

Results of panel OLS regressions at the financing round level. The dependent variables are dummy variables indicating whether a company receives Angel or VC financing in the current round. The main independent variables are the natural log of 0.01 plus the prior cumulative number of patent applications, the natural log of 0.01 plus the financing need in the current round, the natural log of 0.01 plus the financing need in subsequent rounds, and the nature log of the sum of financing need in the current and subsequent rounds. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Receiving Financing in Current Round Dummy							
	1	2	3	4	5	6	7	8
VARIABLES	Angel Dummy	VC Dummy	Angel Dummy	VC Dummy	Angel Dummy	VC Dummy	Angel Dummy	VC Dummy
Log Prior Cumulative Number Applications	-0.00699	0.0211**	-0.00567	0.0155**	-0.001000	0.0113	0.000789	0.00600
	(0.00864)	(0.00820)	(0.00855)	(0.00759)	(0.00853)	(0.00731)	(0.00846)	(0.00715)
Log Current Financing Need			-0.0104**	0.0673***	-0.00820	0.0660***		
			(0.00513)	(0.00592)	(0.00507)	(0.00599)		
Log Future Financing Need					-0.0186***	0.0174***		
					(0.00462)	(0.00405)		
Log of Sum of Current & Future Financing Need							-0.0437***	0.0867***
							(0.00812)	(0.00539)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710	1,710	1,710	1,710	1,710
Number of Companies	468	468	468	468	468	468	468	468
R-Squared	0.305	0.358	0.323	0.519	0.345	0.536	0.363	0.513

Table 9: Patents on Current Financing – Match on Financing Needs.

Results of panel OLS regressions at the financing round level. The dependent variables are the natural logarithm of 0.01 plus the current investment amounts from Angel-Single, Angel-Multiple, and VCs. The main independent variables are the natural logarithm of 0.01 plus the cumulative number of patent applications. The unreported control variables are company age at the first financing round, previous round amount, region dummies, industry dummies, share registry dummy, three (quarterly) non-parametric clocks for calendar time, time passed since the previous financing round, and time passed since the first round. A constant was also included but not shown. All variables are defined in Table A1 in the Appendix. Robust standard errors are reported in the parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log Investment Amount in Current Round		
	1	2	3
VARIABLES	Angel-Single $	Angel-Multiple $	VC $
Log Prior Cumulative Number Applications	-0.00873	0.157*	0.408***
	(0.123)	(0.0893)	(0.135)
Controls	YES	YES	YES
Observations	1,710	1,710	1,710
Number of Companies	468	468	468
R-squared	0.325	0.149	0.372

Appendix
Table A1: Variable definitions

Main variables.

Variable	Description
(a) Investment	
Angel $	Log of 0.01 plus the investment amount in current financing round by Angel investors
Angel-Single $	Log of 0.01 plus the investment amount in current financing round by Angel investors, who invest in only one company in the entire dataset.
Angel-Multiple $	Log of 0.01 plus the investment amount in current financing round by Angel investors, who invest in more than one companies in the entire dataset.
VC $	Log of 0.01 plus the investment amount in current financing round by VC investors.
Angel-Outsider $	Log of 0.01 plus the investment amount in current financing round by outsider angel investors, who never invest in the underlying company prior to the current financing round.
Angel-Insider $	Log of 0.01 plus the investment amount in current financing round by insider angel investors, who have invested in the underlying company in previous financing round(s).
VC-Outsider $	Log of 0.01 plus the investment amount in current financing round by outsider VC investors, who never invest in the underlying company prior to the current financing round.
VC-Insider $	Log of 0.01 plus the investment amount in current financing round by insider VC investors, who have invested in the underlying company in previous financing round(s).
Angel-Dummy	Dummy variable indicating the presence of Angel investor in the current financing round.
VC-Dummy	Dummy variable indicating the presence of VC investor in the current financing round.
Angel #	Log of 0.01 plus the number of Angel investors invest in the current financing round.
VC #	Log of 0.01 plus the number of VC investors invest in the current financing round.
(b) Other	
Prior Cumulative Number Applications	Log of 0.01 plus the cumulative number of patent applications.
Prior Cumulative Number Applications – 1 Year	Log of 0.01 plus the cumulative number of patent applications where the effect of patents last for only 1 year.
Prior Cumulative Number Placebo Applications	Log of 0.01 plus the prior cumulative number of placebo patent applications that takes the values of the actual cumulative number of patent applications at various points in the future. Effect of patent lasts forever.

Prior Cumulative Number Placebo Applications	Log of 0.01 plus the prior cumulative number of placebo patent applications that takes the values of the actual cumulative number of patent applications at various points in the future. Effect of patent is limited to 2 years only.
Pre-money Valuation	Log of 0.01 plus the company valuation determined by the current share price and total number of shares outstanding prior to the current financing round.
Post-money Valuation	Log of 0.01 plus the sum of pre-money valuation and total investment made in the current financing round.
Current Financing Need	Log of 0.01 plus investment amounts a company received in the current financing round.
Future Financing Need	Log of 0.01 plus investment amounts a company received in all subsequent financing rounds observed in the data.
Current and Future Financing Need	Log of 0.01 plus the sum of investment amounts a company received in the current and all subsequent financing rounds observed in the data.

Controls variables.

Variable	Description
(a) Company characteristics	
Industry dummies	Set of dummy variables for each of the following industries: Biotech; Cleantech; IT & Telecom; Hi-tech Manufacturing; Hi-tech Services; Tourism; Non Hi-tech Industry; Other industry.
Region dummies	Set of dummy variables for each of the following regions: Greater Vancouver (GVRD); Greater Victoria (CRD); Okanagan/Thomson Valley; and Rest of BC.
(b) Other controls	
Previous Round Amount	Log of 0.01 plus the investment amount that a company receives in the previous financing round.
Age at First Round	Log of 0.25 plus the of the company's age measured at time of first financing (in years).
Calendar Time	Quarterly non-parametric clock, i.e. dummies for each quarter of the data.
Time Since Previous Financing Round	Quarterly non-parametric clock, i.e. dummies that groups observations by time-distance since the previous round.
Time Since First Round	Quarterly non-parametric clock, i.e. dummies that groups observations by time-distance since the first round.
Share Registry Dummy	Dummy variable that takes a value of 1 if the data source of the round information is from the company share registries; and 0 if it stems from the electronic database used by the ministry.