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Three essays in Entrepreneurial Finance:
The role of business model, intellectual property right and inter-organizational ties

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SUMMARY

This thesis contributes to literature on financing entrepreneurial ventures by looking at different attributes of entrepreneurial ventures. It particularly studies the role of Business Model, Patents and Discontinued investment by previous investors. The thesis is structured in three separate chapters.

The first chapter investigates the impact of adopting Open Business Model by entrepreneurial ventures on the quality of VC financing and governance of the investment. We do so by comparing proprietary and open source software entrepreneurial ventures. The quality and governance are expected to differ since entrepreneurial ventures, which adopt open business model, are associated with higher complexity and risk. Empirical analysis are based on 514 software entrepreneurial ventures in North America that received VC funding in 6,555 different deals extracted from VentureXpert. The results show entrepreneurial ventures with open business model receive funding from VCs that are more connected in the network of investors and have higher quality. Also, entrepreneurs that adopt Open Business Model are monitored more intensively through more frequent staged investment rounds.

The second chapter drawing on the literature of information asymmetry and signaling looks at patents as reputation signals in Initial Public Offering (IPO) and investigate the fate of those patents once they have been granted. The chapter builds on works that looks at patents as reputation signals and expand the literature by analyzing the fate of those patents once they have been granted. By acting

as a signal, patents can inform observers about attributes of not just the patent, but the patentee itself, and if patents are correlated with less readily observable firm characteristics, patents can serve as a signal of firm quality, more specifically, how innovative a firm is. Using a multi-industry sample of 30,891 US patents from 385 assignees, we find a significant and positive relationship between the likelihood of patents expiring due to lack of maintenance fee payments and the time to IPO. We also find that patents associated with entrepreneurial ventures which are not venture capital backed, are more likely to expire.

The third chapter investigates how early termination of VC investment in entrepreneurial ventures–affects the ability of these young ventures into acquiring further resources necessary for survival and growth. We propose that young entrepreneurial ventures face a higher cost of external financing if existing investors stop investing in the next rounds of financing. The continuation of investment by existing investors confers a positive signal about the quality of young ventures. Hence young ventures, as endorsed by further commitment of capital, are more likely to perform better than otherwise comparable ventures that lack escalated commitment. The chapter contributes to the literature that investigates the role of inter-organizational ties as information about the quality of entrepreneurial venture. Using 5,016 rounds of VC investments in 1,728 entrepreneurial ventures that received more than one round of investment we find that early VC termination in a new venture is a negative signal of the quality of the venture and lead to reduction in the size of investment and the quality of future investors in the next round of investment.

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This thesis is a collection of three research papers which has been done with collaboration with international researchers. The work in Chapter 1 is co-authored with Prof. Massimo G. Colombo (Politecnico di Milano), Prof. Duglas Cumming (York University), Prof. Cristina Rossi-Lamastra (Politecnico di Milano) and Prof. Anu Wadhwa (EPFL). The Chapter 2 is co-authored with Prof. Mehdi Beyhaghi (University of Texas, San Antonio) and Nada Basir (York University). The Chapter 3 is co-authored with M.Shafizade (Politecnico di Milano) and Dr. Sofia Johan (York University). I would like to thank my co-authors and I hope to be able continue this relationship in the future. Thank you for sharing your expertise. It has been a pleasure to work together.

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A. INTRODUCTION

A.1. OVERVIEW OF THE DISSERTATION

Surge of studies on entrepreneurial ventures is motivated by the belief that entrepreneurial ventures are the engine of economics, technological and employment growth[1] (Scherer, 1991; Audretsch, 1995). During 1980s entrepreneurial ventures added 16 million new jobs in the U.S. (Birch, 1989). The trend has persisted in 1990s and based on Census Bureau data, entrepreneurial ventures accounted for 79 percent of new jobs (Edmiston, 2004). Similar pattern exists in Europe. For instance in the UK in the period of 1997-2008, 65 percent of new jobs were created by small entrepreneurial ventures (Hijzen et al., 2010). Similarly, Scherer (1991) showed that small entrepreneurial ventures produced more invention in comparison with the large counterparts. Much of this studies focus on high-tech entrepreneurial ventures.

High-tech Entrepreneurial ventures are prone to financial constraints and difficulty in accessing to external financing manly due to agency problem (Jensen and Meckling, 1976) and information asymmetry (Akerlof, 1970; Myers and Majluf, 1984). Financial resource constraints are often claimed to slow down the growth of entrepreneurial ventures (Carpenter & Petersen, 2002). The short track of record and lack of collateral in addition to uncertainties about the return on investment in high-tech project are the main sources of difficulty in raising external financing (Carpenter & Petersen, 2002). By the end of 1980s a stream of literature on studying financing and financiers of young entrepreneurial ventures emerged (Denis, 2004) and is rapidly growing. Much of this literature focuses on equity financing. This thesis, in three separate chapters, contributes to the literature studying equity financing of entrepreneurial ventures.

[1] "*The spectacular success stories of companies such as Microsoft, Genentech, and Federal Express embody the sense that new venture creation is the sine qua non of future productivity gains*." (Berger &Udell, 1998)

The first chapter investigates impact of adopting Open Business Model by entrepreneurial ventures on the quality of VC financing and governance of the investment. Business model is reflecting "*management hypothesis about what customers want, how they want it, and how an enterprise can best meet those needs and get paid for doing so*" (Teece, 2010). Hence business model sketch the business logic of how to manage resource and exploit knowledge, how to create and capture value for stakeholders and define the landscape that venture operates (Amit & Zott, 2001; Trimi & Berbegal-Mirabent, 2012; Casadesus-Masanell & Ricart, 2010). The essence of business model of a venture is in its system of activities and revenue generation model (Gambardella & McGahan, 2010). We study business models by distinguishing among entrepreneurial ventures adopting a traditional Closed Business Model and Open Business Model. Traditionally firms develop a technology internally and commercialize and scale their product by acquiring downstream complementary assets such as manufacturing, marketing, sales, etc. In this model revenue generation focuses on isolating mechanisms by mean of Intellectual property rights (IPRs) in order to achieve monopoly rents (Barney, 1991). The business model of these ventures is referred to as closed business model (CBM). However Recently ventures opened up their innovation processes which allow them to access external knowledge sources along with internal ones (Chesbrough, 2006). The new innovation process requires mechanisms that venture should employ to create and capture value. Chesbrough (2006) refers to these mechanisms as "open business model" (OBM). In the OBM Innovation is a joint effort of external and internal knowledge sources (Lakhani & von Hippel, 2003; Chesbrough, 2006) and revealing technology and knowledge is an essential means for creating synergies between external and internal knowledge sources (Alexy &George 2013). These two main characteristics of OBM cause complexity in the system of activities and revenue generation of ventures. Hence in OBM viability and sustainability of revenue generation model along with complexities stem from the system of activities are the main concerns. On the other word, while OBM in comparison with CBM has better value creation due to access to external knowledge sources, it has inferior value capture since technology is freely available (partly of fully) (Casadesus-Masanell & Llanes, 2011; West, 2007).

In this chapter, we empirically investigate the impact of adopting open business model by entrepreneurial ventures on the quality of VC financing and governance of the investment. The quality and governance are expected to differ since entrepreneurial ventures, which adopt open business model, are associated with higher complexity and risk. Empirical analysis are based on 514 software entrepreneurial ventures in North America that received VC funding in 6,555 different deals extracted from VentureXpert. The results show entrepreneurial ventures with open business model receive funding from higher quality VCs. Also, entrepreneurs that engage in community collaboration are monitored more intensively through more frequent staged investment rounds.

The second chapter drawing on the literature of information asymmetry and signaling looks at patents as reputation signals in IPO and investigate the fate of those patents once they have been granted. The primary focus of value for many corporations has been found in their intellectual property rights with inventors spending millions of dollars to protect their inventions. Prior research has explored the different motives for patenting including blocking competitors (Cohen et al., 2000), creating "fences" around commercialized products in order to prevent others from designing and selling substitute products (Cohen et al., 2000; Shapiro, 2001.), defending against patent infringement (Hall et al., 2005; Hall & Ziedonis, 2001), and as a way to increase a firm's reputation by showing it is innovative and an attractive investment (Blind et al., 2006; Hall & Ziedonis, 2001).

Access to external financing has been identified as the second most important reason of patenting for entrepreneurial ventures (Graham et al., 2010.). The role of patent in accessing external financing in early stage of entrepreneurial ventures is small (Mann, 2005), While the value of the patent is significantly larger for later stage and revenue-generating entrepreneurial ventures. Investors consider patent as a strategic tool that might provide sustainable market power and differentiation. Cao et al., (2013) shows IPOs with prior patents outperform the ones without patent. Heeley et al., (2007) argue patent are reducing underpricing in industries where the link between patents and inventive returns is transparent.

Once issued, a patent remains in force until 20 years after the patent application was originally filed. To keep this 20-year term, the patent holder must pay maintenance fees at the four year, eight years, and twelve year mark. However, between 55 and 67 percent of issued U.S. patents lapse for failure to pay these fees before the end of their term (Lemley, 2000, 2001; Moore, 2005). Although many of these undeveloped inventions can be considered commercially worthless, the problem of underutilized patents arguably applies to a large share of potentially valuable inventions. These patents are not only underutilized, but they may also prevent other firms from using them, thus potentially thwarting the evolution of innovation within an industry. Using renewal data we investigate whether patents are underutilized or not.

The chapter builds on works that look at patents as reputation signals (Hsu & Ziedonis 2013; Long 2002; Conti et al., 2013); and expand the literature by analyzing the fate of those patents once they have been granted. By acting as a signal, patents can inform observers about attributes of not just the patent, but the patentee itself, and if patents are correlated with less readily observable firm characteristics, patents can serve as a signal of firm quality, more specifically, how innovative a firm is (Lemley, 2001). Using a sample of 30,891 US patents from 385 assignees, we argue that patents that are used for signaling are more likely to be underutilized once their purpose has been exercised. We find a significant and positive relationship between the likelihood of patents expiring due to lack of maintenance fee payments and the time to IPO. We also find that patents associated with firms which are not venture capital backed, are more likely to expire.

The third chapter investigates how early termination of VC investment in entrepreneurial ventures–affects the ability of these young ventures into acquiring further resources necessary for survival and growth. We propose that young entrepreneurial ventures face a higher cost of external financing if existing investors stop investing in the next rounds of financing. When a VC decides to adopt a wait-and-see approach by stopping re-investment, it indicates a serious revision of its prior expectations from the venture. Even if other VC firms fund the venture, the shares of the focal VC may severely dilute. Since the opportunity cost of leaving money on the table is high for the investor, the revised expectation of the focal venture by an inside investor should send a negative signal to the community of VC investors. Though the downside cost of early termination for focal VC is limited to its pecuniary loss (sunk cost of investment if any), its consequence for the venture is not yet studied. Early termination of investment in a venture may leave ventures prone to newness, hindering acquisition of further financing.

Future investors, faced with great unobservable qualities of young companies and the uncertainty surrounding their financial prospect, rely on observable characteristics to appraise a company. The continuation of investment by existing investors confers a positive signal about the quality of young ventures. Hence young ventures, as endorsed by further commitment of capital, are more likely to perform better than otherwise comparable ventures that lack such the escalated commitment. Using 5,016 rounds of VC investments in 1,728 entrepreneurial ventures that received more than one round of investment the chapter demonstrates that early VC termination in a new venture is a negative signal of the quality of the venture, reducing the size of investment and the quality of investors. And we also find that the marginal effect of early termination of investment is significantly larger for prominent VC and generalist VC (investing in all stages of investment).

A.2. CONTRIBUTION

This section highlights the general contribution of thesis and briefly explains the contribution of each chapter.

The literature on financing young entrepreneurial ventures focuses on the issue of information asymmetry (Amit et al., 1998; Amit et al., 1990; Gorman & Sahlman, 1989; Sahlman, 1990; Berger & Udell, 1998; Gompers, 1995), which can lead to adverse selection and moral hazard (Stiglitz, 1985; Pauly, 1974.). The short track record of entrepreneurial ventures by which the quality is assessable, possess a challenge for the evaluation to investors and increase information asymmetry (Amit et al., 1998; Carpenter and Peterse, 2002). In addition, high-tech ventures are risky since the development of new technologies is associated with high uncertainty and the market adoption is not yet foreseen and speculative (Hall, 2002). The compounded uncertainty of young high-tech ventures can only be mitigated if there is a direct way to observe the quality of young ventures (Leland & Pyle, 1977).

There are three categories of information (entrepreneur, business and affiliates) that influence the perception of quality judgment of young ventures. First, entrepreneurs' human capital (Dimov & Shepherd, 2005; Cooper et al., 1994; Hsu, 2007) is initially considered a valuable asset and determinant of venture success. Evidence suggests that VCs overestimate the role of start-ups' human capital for the future success (Baum & Silverman, 2004) by attaching considerable selection attention (see Colombo & Grilli, 2010). The second category of relevant information to future investors is related to the business opportunities (Kaplan &

Stromberg, 2004; Kaplan et al., 2009) and previous accomplishments of the firms (Hallen, 2008), be its patents (Hsu & Ziedonis, 2013) or product prototype (Audretsch et al., 2012). For instance, prototype signals the feasibility of the technology and in combination with patents attracts potential investors (Audretsch et al., 2012). Third category of information that evaluators can use to assess the quality of the nascent venture is the attributes of inter-organizational ties (Stuart et al. 1999). Affiliation with prominent strategic alliance partners, well-connected VCs and reputable bank underwriters (Gulati & Higgins, 2003) are positively associated with the quality of the entrepreneurial firms.

This thesis contributes to the studies looking at different attributes of entrepreneurial ventures, which can convey information about future prospect of entrepreneurial venture, and their effect on the financing. It focuses on business and previous accomplishments, namely business model and patents in addition to inter-organizational ties; early termination of investment by VC.

Apart from the general contribution of the thesis that was mentioned, each chapter contributes to several streams of literature.

The first chapter contributes to two strands of literature. First, it contributes to the strand of literature that investigates the relationship between entrepreneurial venture's characteristics and VC investment. While prior research highlighted the importance of business model in VC financing, but empirical studies treat entrepreneurial ventures homogenous regarding their business models. We contribute to these studies by focusing on different business models (open VS. closed) of entrepreneurial ventures and its impact on VC financing. Second, Prior research, which has explored Open Business Model, by using qualitative and anecdotal evidences, speculated benefits of Open Business Model. However, scholars have rarely explored the financing of ventures adopting Open Business Model. The chapter contributes to this stream of literature by arguing what type of investors are more likely to invest in Open Business Model and how they monitor entrepreneurial ventures adopting Open Business Model.

The Second chapter, firstly contributes to the works that look at patents as reputation signals (Hsu & Ziedonis, 2013; Long, 2002; Conti et al., 2013); and expand the literature by analyzing the fate of those patents once they have been granted. Secondly, it contributes to the literature that study how firms in IPO get involved in reputation building by sending the signal of quality try to help investors to sort quality of firms. The third contribution of study stems from its focus on the life cycle of patents. Particularly, as there is very little work on underutilized patents (see Moore, 2005 for an exception), this study offers a unique opportunity to track the creation and evolution of patents that fail to commercialize.

The third chapter contributes to studies that assess the impact of inter-organizational ties (Stuart et al., 1999) of the entrepreneurial venture and external financing by demonstrating that early VC termination in a new venture is a negative signal of the quality of the venture, increasing the cost of external financing. Furthermore, the chapter contributes to the studies related to the dynamics of syndication structure in VC investments. Cumming and Dai (2012) assess the antecedents and consequences of switching the lead investor for an entrepreneurial venture in the subsequent round of financing. Although the actions of lead investor are of paramount importance, it is not sufficiently comprehensive. Hence, in the context of VC other members of syndication and their interactions matter. The chapter also contributes to the stream of VC research on “escalation of commitment”, that is, the failure to terminate investment in low-quality ventures (Birmingham et al., 2003). The normative pressures from co-investors to fund the follow-up round (Guler, 2007) influence VCs to continue investment in failing or so-called “living dead” ventures (Ruhnka et al., 1992). We put forward empirical evidence into the logic of normative pressure, arguing that early termination of VC investment just reflects the concerns of VCs about the negative signal to the VC community.

A.3. BRIEF LITERATURE REVIEW OF ENTREPRENEURIAL FINANCE

While each chapter includes a comprehensive review of relevant literature, in this section I provide a short review of literature on entrepreneurial finance and relevant issues. This section does not mean to review an exhaustive issues related to entrepreneurial finance but tries to focus on general issues which are relevant to all chapters of the thesis.

Entrepreneurial ventures account for significant wealth generated by economic systems and are an important source of employment growth and technological development[2] (Audretsch, 1995; Becker & Gordon, 1966). Entrepreneurial ventures are different from established firms in several aspects. They are constrained in access to financial, technological and human resources (Becker & Gordon, 1966), lack sophisticated governance structure (Ambos & Birkinshaw, 2010) and suffer from scanty legitimacy (Stinchcombe, 1965).

Financial resource constraints are often mentioned as main reason in slowing down the growth of entrepreneurial ventures (Carpenter & Petersen, 2002). Entrepreneurial ventures encounter severe problems in rising external financing for their innovation activities (Hall, 2002) since these ventures lack a track of record while their knowledge-intensive innovation projects are characterized by high uncertainty and information asymmetries, which make it difficult for external investors to evaluate their future prospects. In addition, high-tech entrepreneurial ventures usually are short of tangible assets that can be pledged as collaterals

[2] "*Innovation -- particularly in the high tech, information, and bio-technology areas -- is vitally dependent on a flourishing entrepreneurial sector.*" *(Berger and Udell, 1998)*

(Carpenter & Petersen, 2002). Consequently, their access to traditional sources of financing such as borrowing is limited (Berger & Udell, 1998).

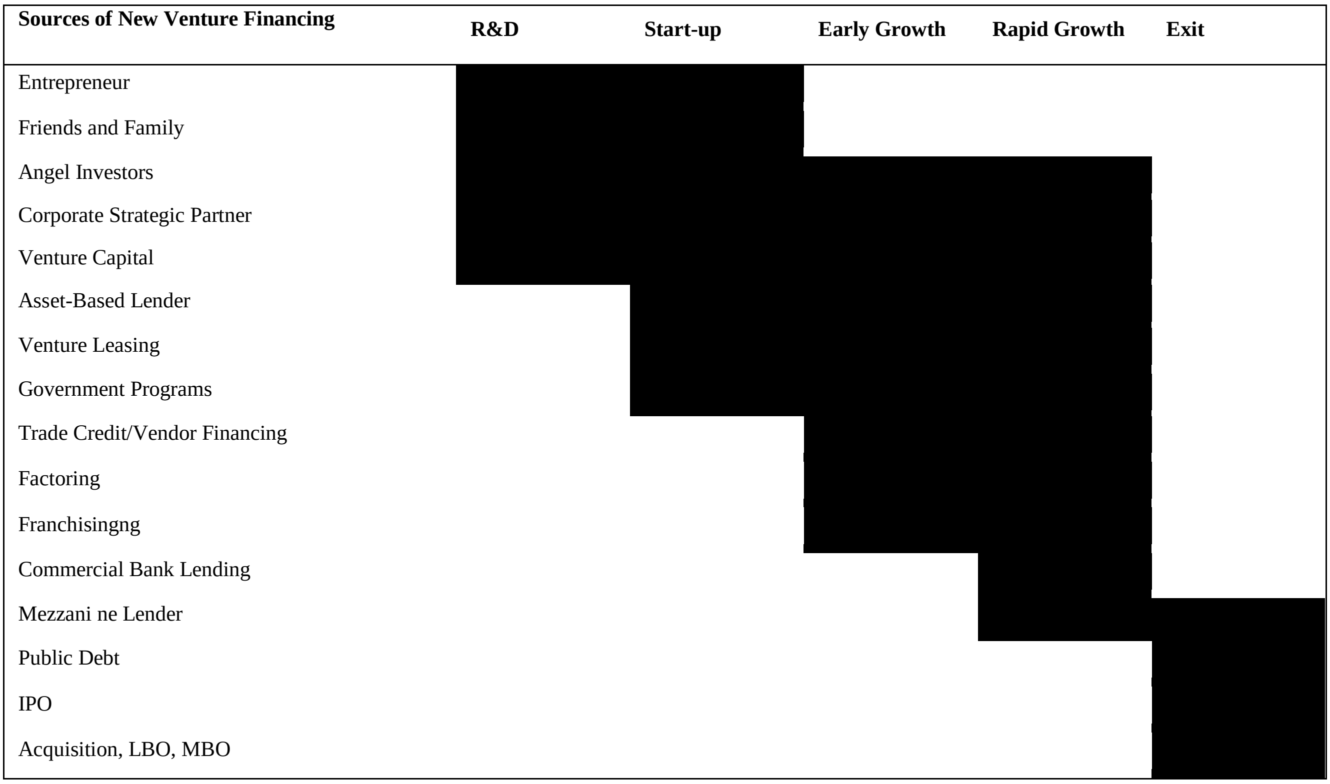
The problems of rising external financing and sources of financing evolve during the life cycle of entrepreneurial ventures from a business opportunity till exit. During each stage a venture from an idea with no management team, no prototype and patent moves toward organizations with organizational structure, products and getting ready for an exit through going public, being acquired or merge, etc (Smith et al., 2011)[3]. Depending on the stage of entrepreneurial venture the sources of financing also varies. The figure A-1 shows different sources of financing for an entrepreneurial venture and the stage of development.

This thesis focuses on two of the most significant sources of financing; Venture Capital (VC) and Initial Public offering (IPO). Venture Capital industry received an extensive attention from scholars, practitioners and policy makers in the last 30 years. According to MoneyTree™ Report of PricewaterhouseCoopers (PWC)[4], the size of VC investment grows from around 8 $b in 1995 to around 27 $b in 2012 with a peak of 105 $b in 2000 due to investments in information technology known as bubble period[5]. Venture Capital (for a review see Da Rin et al. (2011)) firms are usually organized as limited partners in whom general partners manage and invest funds raised from limited partners (Gompers & Lerner, 1999). Limited partners can be institutional investors or wealthy individuals. Each fund has a limited life span of usually 10 years. General partners in VC firms manage the fund by investing in portfolio companies which have passed several scrutiny processes. Since VCs have relative efficiency in selecting and monitoring their investment portfolio (Amit et al., 1998), they often specialize in high-risk ventures in high-technology industries (Gompers &

3 "*What started out as a dream has become an entrepreneurial reality*". http://www.jbv.com/lessons-CES/finance.htm
4 https://www.pwcmoneytree.com/MTPublic/ns/index.jsp
5 Since 2000 on average every day 200 new VC fund was created (Da Rin et al., 2011)

Lerner, 2001; Hellmann & Puri, 2002). The importance of VC is in alleviating information gaps about entrepreneurial ventures and helping them to receive the financing which they cannot access from other sources (Gompers & Lerner, 2001; Bertoni et al., 2013).

Figure A-1- Sources of new venture financing (Smith et al., 2011)



VCs not only provide capital but also monitor and support their portfolio companies (Ueda, 2004; Sapienza et al., 1996; Gompers & Lerner, 1999; Macmillan et al., 1989). For example, previous studies showed the positive impact of VCs on innovation in both industry level (Kortum & Lerner, 2000; Hirukawa & Ueda 2011) and company level (Chemmanur et al., 2011; Hellmann & Puri, 2000), employment and sales growth (Bertoni et al., 2011), speed of product to the market (Hellmann & Puri, 2000) and professionalization (Hellmann & Puri, 2002). VCs vary significantly in the value they can add to the entrepreneurial ventures. Hsu (2004) shows the importance of the value added services that VC provides for the entrepreneur. He showed entrepreneurs are willing to accept lower valuation in exchange with association with high quality and reputable VCs.

The VC monetizes the return on investment through the exit and selling their share (Gompers & Lerner, 2001). They are several options for exit. An exit through IPO usually provides the highest rate of return for investors (Gompers & Lerner, 1999) following with an acquisition at a favorable price. In the period of 1980-2012 about 36% of all IPOs in US were VC backed companies[6]. Not only the IPO is the most profitable exit for VC but also is the most important milestone for the ventures (Chemmanur et al., 2010). An extensive literature has studied IPO (for a review see Ritter & Welch, 2002; Certo et al., 2009). The traditional finance and economic literature argue that IPO is simply a stage in the growth of a company which provides access to public capital and lowers the cost of capital for ventures (Pagano et al., 1998). From 1980 to 2001 ventures were able to raise $78 million per deal in IPO market and create a return of on average 18.8 percent for investors in the first day of trading (Ritter & Welch, 2002). A recent stream of literature has documented other strategic motives for going public such as creation of public shares for acquisition (Brau & Fawcett, 2006). Moreover, The IPO serves as a strategic tool for high-tech ventures by enhancing the reputation of venture (Brau & Fawcett, 2006). The IPO is also beneficial for founders and shareholders which allow them to diversify their portfolio by cashing in their equity (Black & Gilson, 1998; Zingales, 1995).

The literature on financing young entrepreneurial ventures focuses on the issue of information asymmetry, which can lead to adverse selection and moral hazard (Stiglitz, 1985; Pauly, 1974.; Leland & Pyle, 1977). Adverse selection is related to hidden information and occurs when one side of transaction “here entrepreneur” knows relevant information which are not known for the other party “here investor”. This situation can lead to “lemon market problem” (Akerlof, 1970) in which high quality projects go out of market since investors are not able to identify the quality of projects. Hence, they request a lower price which can lead

[6] Ritter, 2013 , http://bear.warrington.ufl.edu/ritter/IPOs2012VC-backed.pdf

high quality projects to leave the market. Moral hazard refers to “hidden action”, in which investors are not able to observe behavior of entrepreneur. In this case entrepreneur may engage in actions for personal gain in the expense of investors (agency problem). “*For projects of good quality to be financed, information transfer must occur*” (Leland & Pyle, 1977). Leland and Pyle (1977) show the role of signaling[7] and financial intermediaries such as VC in facilitating information transfer and increasing market efficiency.

In the context of venture capital investment screening, contracting and monitoring mechanism are designed to minimize the moral hazard and adverse selection problem (Berger & Udell, 1998). Screening starts with a comprehensive due diligence about business, market and etc. prior the investment which lead to design of appropriate contract (Berger & Udell, 1998). Sahlman (1990) highlighted importance of contract design in minimizing agency cost. He argues about the role of stage investment and compensations linked to performance as important monitoring mechanisms used by VCs in minimizing agency problem. Amit et al., (1998) argues the importance of VC in alleviating information asymmetry and consequently adverse selection. Amit et al. (1998) argues even that VC are tend to specialize in uncertain and high risk industries, but within these sectors they prefer venture with less information asymmetries. This is possible by evaluation of observable attributes of entrepreneurial ventures. These attributes can be Patent (Hsu & Ziodenis, 2013; Conti et al., 2013; Mann and Sager, 2007), Prototype (Audretsch et al., 2012), business opportunity (Kaplan et al., 2009), Social and organizational ties (Stuart et al., 1999; Shane & Cable, 2002), human capital (Hsu, 2007; Colombo & Grilli, 2010), etc.

Similarly in the IPO market information asymmetry lead to complication in firm valuation and may lead to underpricing in the expense of entrepreneur (Ibbotson & Ritter,

[7]“ the entrepreneur’s willingness to invest in his own project can serve as a signal of project quality” (Leland & Pyle, 1977).

1995). In order to mitigate this problem in IPO, regulators obliged ventures to disclose critical financial and business information such as performance, board members, Top Management Team, Compensation Contracts, Investors and underwriter in IPO prospectus (Certo et al., 2009). In U.S this process is through submitting S-1 form to U.S. Securities and Exchange Commission (SEC). Following filing issuers primarily through underwriters engage in marketing their equity to potential investors (i.e. Institutional investors), this process is known as “book-building” (Bernstein, 2012).

The disclosure not only help investors to evaluate the value of equity but allow ventures involve in reputation building and by sending signal of quality try to help investors to sort quality of firms. For example, literature studied the role of the reputations of investment bankers, auditors (Beatty, 1989), venture capitalists (Megginson & Weiss, 1991), perceptions of board prestige (Certo, 2003) and the top management (Higgins & Gulati, 2006) as a signal of quality in IPO (for a review of different signals in IPO see Connelly et al., 2010).

The rest of this thesis is structured as following. The first chapter investigates impact of adopting open business model by entrepreneurial ventures on the quality of VC financing and governance of the investment. The second chapter drawing on the literature of information asymmetry and signaling looks at patents as reputation signals in IPO and investigate the fate of those patents once they have been granted. The third chapter investigates how early termination of VC investment in entrepreneurial ventures-affects the ability of these young ventures into acquiring further resources necessary for survival and growth.

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CHAPTER 1

1. CHAPTER 1: OPEN BUSINESS MODELS AND VENTURE CAPITAL FINANCE [8]

[8] This chapter is based on Working paper : Colombo, M; Cumming , D; Mohammadi ,A; Rossi_lamastra, C and Wadhwa, A (2013), “Open Business Model and Venture Capital Finance”.

1.1.INTRODUCTION

Technology -based entrepreneurial ventures are a prominent means through which jobs, innovations and new technologies are created (e.g., Audretsch, 1995). Some of the key choices and decisions that an entrepreneurial venture makes during its evolution are reflected in its business model, that is, the way that the venture expects to create and capture value from its underlying technology (Teece, 2010). Because it involves decisions related to the system of activities the venture will undertake (Amit & Zott 2001) and its revenue generation mechanism (Teece, 2010), the business model that a venture chooses can have important implications for its growth and performance (George & Bock 2011; Zott & Amit 2007; Chesbrough & Rosenbloom 2002; Patzelt , Knyphausen-Aufsess, & Nikol, 2008). Despite their salience in a venture's evolution, business models have only recently begun attracting scholarly attention (Zott, Amit, & Massa, 2011).

Traditionally, technology-based entrepreneurial ventures have focused on creating value through *closed* business models in which the locus of innovation and the system of activities are concentrated within the venture's boundaries and revenue generation occurs by creating isolating mechanisms via intellectual property rights (IPRs) to achieve monopoly rents (Barney, 1991). However, increasing competition and cost of product development have led more and more ventures to open up their innovation processes and adopt "open" business models (Chesbrough, 2006) which have two distinctive features. First, open business models involve creating value through greater utilization of external knowledge sources such that the locus of innovation and the system of activities undertaken by the venture extend outside its boundaries (Chesbrough, 2006). Second, because creating synergies between external and internal knowledge sources requires ventures to engage in selective revealing (Henkel, 2009; Alexy & George 2013), ventures are not able to rely on intellectual property rights as the primary means of generating revenues (Casadesus-Masanell & Llanes, 2011). Even though adopting open buisiness model may help ventures in creating value through increasing innovative performance (Laursen & Salter, 2006), cutting costs (Lakhani & von Hippel, 2003), and improving the quality of products (Chesbrough, 2003), these benefits are accompanied by greater complexity in the system of activities which has implications for the viability and sustainability of the revenue generation model. In other words, open buisiness model may involve a trade-off between value creation and value capture, exacerbating the uncertainty about the ventures which are adopting them. Thus, adoption of open buisiness model by technology-based entrepreneurial ventures presents an interesting and important dilemma, which has been overlooked in the literature: given the substantial uncertainty related to value capture inherent in open business models, how do ventures adopting open business models succeed in attracting the resources and partners necessary for growth and survival?

This paper sheds light on this dilemma by examining the type of venture capital (VC) financing that entrepreneurial ventures are able to attract when they adopt an open business model as compared to ventures that adopt a closed business model. Scholars agree that VC is one of the key means of obtaining financing for technology-based entrepreneurial ventures because the substantial uncertainty and information asymmetry associated with such ventures may prevent access to traditional sources of finance (Berger &Udell, 1998; Carpenter & Petersen, 2002; Hall, 2002; Hall & Lerner, 2012). VC investors are able to carefully scrutinize entrepreneurial ventures before investing and closely monitor them after the investment (Gorman & Sahlman, 1989; Gompers & Lerner, 1999). They also add value to portfolio firms through coaching and the access to their network of business contacts (Sapienza & Timmons, 1989; Hochberg, Ljungqvist, & Lu, 2007). Lastly, VC investments provide a quality signal making it easier for portfolio firms to collect additional resources from uninformed third parties (Megginson &Weiss, 1991). Accordingly, VC investments have been shown to have a strong positive effect on various measures of venture performance, such as successful exits

(Hsu, 2006), Total Factor Productivity and sales growth (Bertoni, Colombo, & Grilli, 2011; Chemmanur, Krishnan, & Nandy, 2011).

Prior literature provides some qualitative evidence that the business model adopted by entrepreneurial ventures to commercialize their technology is an important aspect that influences selection by VC investors (Kaplan & Stromberg, 2004). However, the link between entrepreneurial ventures' business model and VC finance has not been adequately investigated. To fill this gap, we compare VC-backed entrepreneurial ventures that have adopted an open source software (OSS) business model as an example of an open business model (Chesbrough & Appleyard, 2007) with VC-backed entrepreneurial ventures that develop and sell proprietary software, an example of a closed business model. Given this context, we ask the following related questions: Does the adoption of an OSS business model make entrepreneurial ventures more likely to obtain finance from *higher quality* VC investors? Are VC investors financing OSS entrepreneurial ventures more likely to resort to *syndication* and to more frequent *staging* of VC investments?

Our insights are as follow. OSS entrepreneurial ventures face greater complexity and uncertainty in their system of activities and revenue generation model than their proprietary software counterparts, and consequently, the OSS business model suffers significantly from a lack of legitimacy. Therefore, the superior coaching, monitoring and networking abilities of higher quality VC investors are especially valuable for OSS entrepreneurial ventures, as is the strong quality signal that their investments convey. In addition, because of the greater uncertainty that surrounds the OSS business model, higher quality VC investors which have greater risk tolerance, are more inclined to invest in these firms than their lower quality peers. For the same reasons we also expect VC investments in OSS entrepreneurial ventures to be more likely to be syndicated and to be more frequently staged.

To test our hypotheses, we use a sample of 514 North American VC-backed software entrepreneurial ventures obtained from SDC Platinum (VentureXpert), which received the first round of VC finance in the period 1994-2008. Of these entrepreneurial ventures, 124 adopted an OSS business model, while the remaining entrepreneurial ventures adopted a proprietary software business model. The final sample consists of 6,555 venture - VC dyads, each of which reflects an investment made by a VC in a portfolio venture. 2,029 of these dyads are comprised of an OSS entrepreneurial venture. Our results indicate that VC investors that invest in OSS entrepreneurial ventures are of significantly higher quality than those that invest in proprietary software entrepreneurial ventures. We also observe that OSS entrepreneurial ventures receive a greater number of rounds of VC finance. However, we do not detect any difference between OSS and proprietary software entrepreneurial ventures in terms of the syndication activity of VCs that invest in such ventures. Our results are robust to several robustness checks we performed to control for possible biases in our results.

The contributions of our study are twofold. First, the study addresses a significant gap in the literature on business models and VC financing. In doing so, we respond to the calls by Alexy and George (2013) for further investigation on open business models and different sources of financing. Alexy and George (2013) showed that adopting open business models impacts the value of public firms. We complement the results of their study by focusing on privately held ventures and investigating type of VC financing they are able to attract. Business models are commonly linked to survival and long-term performance of entrepreneurial ventures (George & Bock, 2011). Simialrly, the ability to access high quality VC financing increases chances of survival and success of entrepreneurial ventures (Nahata, 2008; Sorensen 2007). In this study we have shown that entrepreneurial ventures that adopt an open business model are able to to acquire high quality VC financing, which in turn, augments the sustainability and viability of the business model in the long run.

Second, we contribute to the literature on VC financing of entrepreneurial ventures. The literature on VC quality, staging, and syndication focused on the role of uncertainty (Lerner, 1994; Gompers, 1995; Altintig, Chiu, & Goktan, 2013; Tian &Wang, 2011; Petkova, Wadhwa, Yao, & Jain, 2013; Li, 2008; Bygrave, 1987; Casamatta & Haritchabalet 2007; Wang & Zhou, 2004). While prior research has highlighted the importance of business model in VC financing (e.g. Kaplan & Stromberg, 2004), empirical studies treat entrepreneurial ventures as homogenous entities with respect to their business models. In this study we highlight the uncertainties associated with adopting an open business model and show how choice of the business model and uncertainties associated with it, affect VC quality, staging, and syndication.

The paper is structured as follows. Section 2 contrasts the OSS business model with the proprietary software business model and develops the theoretical hypotheses of this study. Section 3 describes the sample and the data collection process, defines the variables and outlines the methodology used for analyzing the data. Section 4 presents the results of our empirical analysis and section 5 discusses the conclusions.

1.2.THEORY AND HYPOTHESES

1.2.1. THE MANAGERIAL CHALLENGES OF THE OSS BUSINESS MODEL

In this paper, we define the business model as the way a firm operates to “create and deliver value to customers” (Teece, 2010: 173). In accordance with previous studies on the topic, we contrast the OSS business model with the proprietary software business model by focusing on the two main dimensions of a business model: the system of activities and the revenue generation mechanism (Amit & Zott 2001; Zott et al., 2011).

Entrepreneurial ventures adopting a proprietary software business model rely on IPRs combined with other appropriability mechanisms (e.g. brand, lead time) to protect the software they develop from imitation, and sell licenses of the machine-code (which is inintelligble to a human being) to capture the value generated by this software. In other words, the revenue generation model of proprietary software ventures is based on the exploitation of a (temporary) monopoly rent generated by their proprietary technology. Proprietary software ventures may collaborate with third parties (e.g., universities, other firms), but their system of activities is centered on their internal R&D and value creation is closely dependent on the human capital of their talented employees who work as software programmers.

Conversely, entrepreneurial ventures embracing an OSS business model leverage the software code and technological knowledge produced and made freely available by the community of OSS developers. The core of the system of activities of OSS entrepreneurial ventures is thus constituted by collaborations with OSS developers: through them OSS ventures get access to technological knowledge and competencies which otherwise they could not acquire or develop internally (Bonaccorsi, Giannangeli, & Rossi, 2006; Piva, Rentocchini, & Rssi-Lamastra, 2012). In the OSS realm, IPRs are designed for favoring instead of forbidding the access by third parties (Gruber & Henkel, 2006). Hence, the revenues of OSS ventures cannot directly come from selling OSS code. The revenue generation model of OSS firms is instead based on the sale of products (software and hardware) or services that leverage the OSS resources (Perr, Appleyard, & Sullivan, 2010).

In particular, the revenue generation models of OSS entrepreneurial ventures can be grouped into two distinct, though conceptually similar, categories. First, OSS ventures may resort to *versioning* (Shapiro & Varian, 1998); while they give away for free a *basic version* of an OSS software, they also sell a proprietary *premium version* of that software, which includes advanced features and is targeted to less price sensitive customers. Examples of this revenue generation model are provided by MySQL and Sleepycat (Goldman & Gabriel, 2005; Perr et al., 2010). The former venture builds on the open source MySQL project which is freely available and monetize on MySQL Pro Server to those who need to redistribute applications (Perr et al., 2010). The latter venture produces all of the code in its open source applications and the main focus of its dual licence model is on redistribution. For the open source community the company offers the OSI[9]-certified Sleepycat Public License (SPL) while for those who require proprietary application redistribution, the venture sells the Sleepycat Commercial License (Perr et al., 2010).

OSS ventures relying on versioning take advantage of the direct and indirect network externalities generated by the diffusion of the basic OSS version (Katz & Shapiro, 1985; Katz & Shapiro, 1994; Gandal, 1995). First, the greater is the number of users of the basic version, the more the basic version is tested and the more feedback is provided to OSS developers, thus improving the quality of both the basic and premium versions of the software. Second, as the number of users of the basic version increases, it becomes possible for customers who buy the premium version to exchange files and knowledge with a larger crowd. Third, the more widespread the diffusion of the basic version, the greater the incentives for OSS developers to produce applications compatible with the basic version. To the extent that these applications are also compatible with the premium version, they increase the value to customers of the premium version.

Second, OSS ventures can generate revenues from selling products or services that are complementary to one (or more) OSS solution(s) made available for free by the OSS community. A prominent example of this revenue generation model is provided by Red Hat, which monetizes on providing support and updates for the Linux operating system whose code is freely available on the Internet. Other ventures use the Linux operating system in combination with proprietary hardware devices like mobile phones and machine controls (Gruber & Henkel, 2006). LynuxWorks and MontaVista are examples of these ventures.The

[9] Open Source Initiative

fact that the OSS solutions are free of charge reduces the price that OSS ventures can charge for the complementary products and services, thereby increasing their demand. In addition, the free availability of the OSS solutions favors their diffusion and makes them more valuable to customers because of the direct and indirect network externalities typical of the software realm (Katz & Shapiro, 1985). This further increases the value to the customers of the complementary products and services. Obviously, this revenue generation model is viable provided that complementary products and services are sold in an imperfectly competitive market (Fosfuri, Giarratana, & Luzzi, 2008). This happens when an OSS venture controls unique assets that are difficult to replicate for potential competitors and confers it an advantage in the market of the complementary products and services (Teece, 1986). Examples of these assets include ownership of the hardware technology or commercial assets, like a reputed brand or an effective sale force.

The core intuition of this paper is that the OSS business model poses severe challenges relating to both the system of activities and the revenue generation mechanisms. Hence, the returns generated by an OSS business model are more uncertain than those generated by a proprietary software business model.

As regards the system of activities, OSS ventures' collaborations with OSS developers are far from simple because these firms do not have the full control of the OSS development process (O'Mahony & Bechky, 2008; Colombo & Rossi-Lamastra, 2013; Dahlander & Magnusson, 2008). The OSS community is potentially open to everybody. While some OSS developers are eager to signal their talent by developing high-quality software with the aim of obtaining a better job, others write OSS code just for fun and are less committed to quality (von Krogh, Haefliger, Spaeth, & Wallin, 2012; Lerner & Tirole, 2002). Moreover, while OSS developers may receive monetary compensation from OSS ventures for their OSS development activities, these activities are usually not ruled by formal contracts and OSS developers are not employees of the OSS projects to which they contribute (O'Mahony, 2002; Dahlander & Magnusson, 2005). Consequently, OSS ventures face difficulty in aligning the objectives of OSS developers with their own objectives. Project discontinuity[10], departure from the initial specifications, delays in software delivery or delivery of low quality software are concrete risks that managers of OSS ventures have to deal with in OSS projects (O'Mahony & Ferraro, 2007; Dahlander &Magnusson, 2008).

OSS ventures can limit the aforementioned risks by directly contributing to OSS projects (Henkel, 2009). For instance, OSS ventures often pay their employees to contribute to OSS projects or sponsor the most prolific developers in the OSS community (Dahlander, Wallin 2006). Direct contributions and sponsorship give OSS ventures visibility within OSS projects and make them able to informally influence their future directions (O'Mahony & Bechky, 2008)[11]. In addition, the OSS community was originally shaped by the ideological concerns of fighting for software freedom and has developed over time complex unwritten norms and values that govern the behavior of its members. Consequently, in order to effectively collaborate with OSS developers, OSS ventures must learn how to comply with these unwritten norms and values.

The aforementioned challenges of OSS ventures' system of activities threaten the viability and sustainability of their revenue generation model. If an OSS venture relies on versioning, unexpected changes in the rate and direction of the development process within OSS projects may reduce the quality of the OSS basic version of the software or generate delays in the delivery of updates, slowing down its diffusion. This weakens the direct and

[10] Joomla, a content management system (CMS), which is a powerful online application in building web site, is a project that started on August 17, 2005 by developers which were not happy with community management of Mambo project. The "forked" project (Joomla) leads to discontinuation of the Mambo project in 2008 (http://royal.pingdom.com/2008/09/11/10-interesting-open-source-software-forks-and-why-they-happened/).

[11] OSS ventures can also use available codes developed by a OSS project without any significant contribution to the project. Dahlander and Magnusson (2005) refer to this approach as parasitic, and argue that it may create a negative image in the community and even lead to conflicts with the community which perceives the venture as a free rider.

indirect network externalities from which the premium version of the software benefits, and consequently reduces demand for this version. Versioning may also become increasingly difficult if OSS developers improve the quality of the basic version to the level that the premium version has no additional value to the paying customers, who will then self-select in the basic version. If OSS ventures' revenue generation model is based on the sale of products and services that are complementary to OSS solutions, problems in OSS development similar to those illustrated above may reduce the value to customers of the complementary products and services, or force OSS ventures to incur unexpected costs (e.g. to restore compatibility between their products and the OSS solutions).

1.2.2. RESEARCH HYPOTHESES

In the previous section, we have argued that OSS business models are more complex and surrounded by greater uncertainty than proprietary software business models. This is especially troublesome for OSS ventures which require external financing for scaling up their business, as they need to commit to providing a road map and precise milestones so as to be able to attract investors[12]. In this section, we develop a set of theoretical hypotheses relating to the implications for VC financing of the adoption by software firms of an OSS business model. In particular, we argue that because of the greater complexity and uncertainty of the OSS business model, OSS ventures will more likely match with *high quality VC investors*[13] than their counterparts that adopt a proprietary software business model. Moreover, we contend that VC investments in OSS ventures will be more likely to be *staged* and *syndicated* than VC invesments in proprietary software firms.

VC quality.

[12] VCs play an important role in high-tech industries and focus mainly on high-tech entrepreneurial ventures, (Cumming & MacIntosh, 2003) found that 70% of all VC investments are made in technology ventures.

[13] In this paper the term "VC quality" refers to all dimensions which can distinguish a VC investor from its peers regarding its ability to provide value added to portfolio companies, including its investment experience (general and industry), capital under management, previous successful exits, and network centrality.

Scholars in entrepreneurial finance agree that VC investors not only provide capital to entrepreneurial ventures, but also add value to them (Gorman & Sahlman, 1989; Sapienza, 1992; Gompers & Lerner, 1999). High quality VC investors add even more value than other VC investors through three mechanisms. First, high quality VC investors provide better monitoring and coaching. Second, they give entrepreneurial ventures access to a larger network of suppliers, potential customers and candidate executives (Hellmann & Puri, 2002; Hochberg et al., 2007). Third, backing by a high quality VC investor certifies the high quality of the entrepreneurial venture to uninformed third parties, thereby making it easier for the entrepreneurial venture to obtain access to additional financial and non-financial resources (Megginson & Weiss, 1991; Stuart, Hoang, & Hybels, 1999). In accordance with this view, previous studies have found a positive association between the quality of VC investors and the performance of their portfolio firms, as reflected by the probability of getting an additional round of financing (Hochberg et al., 2007), the probability of subsequent successful exit through an IPO and/or a trade sale (Hochberg et al., 2007; Sorensen, 2007; Nahata, 2008), and several measures of long-run post-IPO firm performance (Krishnan, Ivanov, Masulis, & Singh, 2011; Chou, Cheng, & Chien, 2013). Therefore, in the search for VC financing, entrepreneurial ventures struggle to attract high quality VC investors (Hsu, 2004). In support of this argument, (Hsu, 2004) found that offers by high quality VC investors are three times more likely to be accepted by entrepreneurial ventures. Moreover, high quality VC investors manage to acquire equity in entrepreneurial ventures with a 10-14% discount.

Previous studies also showed that VC investors add relatively more value to entrepreneurial ventures which have more complex operations and face greater uncertainty, for instance because they are in an early stage (Sapienza & Timmons, 1989; Timmons & Bygrave, 1986) or are more involved in innovation (Sapienza, 1992; Hellmann & Puri, 2000; Tian & Wang, 2011).

Following this line of reasoning, we expect high quality VC investors to add greater value to entrepreneurial ventures that adopt an OSS business model as compared to ventures that adopt a proprietary software business model. First, the difficulties faced by OSS entrepreneurial ventures in the design and implementation of their business model make the coaching provided by high quality VC investors more valuable for these firms than for proprietary software firms. In particular, high quality VC investors can provide fundamental inputs to design the sophisticated revenue generation mechanisms on which OSS entrepreneurial ventures rely. Moreover, high quality VC investors can help OSS entrepreneurial ventures hire professional managers specialized in community colllaboration, thereby improving their system of activities. Alternatively, owner-managers of OSS entrepreneurial ventures backed by high quality VC investors may specialize in managing collaborations with the OSS community, while delegating other managerial tasks to newly hired professional managers. Second, the OSS business model suffers from a lack of legitimacy[14] as a reliable business model, as it involves actions (e.g., release of software source code to the OSS community) that represent a radical departure from the traditional approach to creating and appropriating value from software development (Alexy & George, 2013). This effect is amplified by the complexity and uncertainty surrounding the OSS business model, and the fact that the free software movement from which OSS was originated, have an anti-business ideology (Stallman, 1984). Hence, being associated with high quality VC investors is more valuable for OSS entrepreneurial ventures than for their proprietary software counterparts, because the quality signal that backing by a high quality VC investor conveys to uninformed third parties clearly is more important for firms that lack legitimacy.

[14] Following (Suchman, 1995) we define legitimacy as the "generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and defnitions".

In sum, high quality VC investors add more value to OSS ventures than they do to proprietary software entrepreneurial ventures. Hence, the former firms can offer high quality VC investors equity at conditions that cannot be matched by the latter firms. Moreover, since the OSS business model requires inputs which low quality VC investors are unlikely to provide, these latter investors are quite unattractive for OSS entrepreneurial ventures and will self-select into entrepreneurial ventures with a less challenging proprietary software business model.

A final consideration is on order. High quality VC investors are likely to be less risk averse than low quality VC investors, as their reputation allows them to raise funds despite the possible disastrous performance of some portfolio companies (Gompers, 1996). Accordingly, high quality VC investors will be more prone to invest in high risk/high return entrepreneurial ventures (Petkova et al., 2013). The higher risk aversion of low quality VC investors further contributes to make OSS entrepreneurial ventures less attractive to them than to high quality VC investors. Overall, the aforementioned arguments suggest the following:

H1: The quality of VC investors that finance OSS entrepreneurial ventures is higher than the quality of VC investors that finance proprietary software entrepreneurial ventures.

Investment staging and syndication.

Staging is the stepwise provision of several rounds of VC finance to entrepreneurial ventures rather than making an upfront investment of all required capital (Sahlman, 1990). Staging offers two main advantages to VC investors (Gompers, 1995; Wang & Zhou, 2004). First, the agency costs engendered by the opportunistic behavior of entrepreneurs are mitigated as the VC investor keeps the option to abandon the venture if the venture fails to meet the milestones set for it. Second, staging creates a real option for the VC investor to stop financing the entrepreneurial venture at each financing round. It allows the VC investor to learn about the entrepreneur and the entrepreneurial venture's operations over time and use the information acquired between each round to make better investment decisions (Bergemann & Hege, 1998).

The extent of agency costs and the value of the exit option provided to VC investors by staging increase with the the uncertainty that surrounds the portfolio firm, thus making staging more valuable (Li, 2008). In accordance with this view, Gompers (1995) showed that lower industry ratios of tangible assets to total assets, higher market-to-book ratios, and greater R&D intensities are associated with more frequent staging. In a similar vein, Tian (2011) found a positive association between the geographical distance between the entrepreneurial venture and the lead VC investor and the likelihood that the VC would stage the investment. Indeed, when distance is greater, collecting information about the entrepreneurial venture is more costly for the VC investor, monitoring is less effective because of lack of relevant information, and so both agency costs and the value of the exit option are greater. It has been also shown that VC investments in younger firms are also more likely to be staged.

Because the business model of OSS entrepreneurial ventures is more complex and their business prospects are more uncertain than those of proprietary software ventures, OSS ventures are more likely to have higher agency costs associated with them, thereby increasing the value of the exit option provided by staging. Thus we expect staging to be more appropriate for VC investments in OSS than for proprietary software ventures. This reasoning leads to the following hypothesis:

H2a: VC investments in OSS entrepreneurial ventures are more frequently staged than VC investments in proprietary software entrepreneurial ventures.

Syndication occurs when two or more VC investors jointly invest in the same entrepreneurial venture. It is a very popular practice among VC investors[15]. Scholars have provided three main motives for syndication of VC investments (Brander, Amit, & Antweiler, 2002; Jaaskelainen, 2012). First, syndication allows syndicate members to share the risk of the syndicated investments. Hence, they can reduce the total risk of their investment portfolio through diversification of the investments (Bygrave, 1987). Second, syndication improves selection of investments, as the quality of target entrepreneurial ventures is evaluated separately and double checked by syndicate members (Lerner, 1994; Casamatta & Haritchabalet, 2007). Third, to the extent that syndicate members have heterogeneous skills, specialization, and network linkages, they can provide more effective coaching to entrepreneurial ventures than individual VC investors, helping them enlarge their resources and capabilities (Tian, 2012).

The available empirical evidence supports the above arguments. Using Canadian data at VC investment level, Brander et al. (2002) showed that syndicated VC investments have higher average returns and higher variability than stand-alone investments. Altintig et al. (2013) highlighted that medical device firms that secured all their VC finance before obtaining FDA approval, when uncertainty about their business prospects is very high, are more likely to be syndicate-backed.Tian (2012) compared a large sample of entrepreneurial ventures backed by a VC syndicate with those backed by an individual VC investor. He showed that VC syndicates tend to invest in young, early stage firms and in earlier financing rounds, where investments are more risky (see also Hopp, 2010; Das, Jo, & Kim, 2011). Moreover, VC syndicates add more value to entrepreneurial ventures than VC investors acting alone. After controlling for the endogeneity of VC syndicate formation, syndicate-

[15] In the period 1980-2005, about 70% of the 30,861 entreprenerial ventures considered by Tian (2012) were syndicate-backed. Data from the VICO database relating to 1,663 VC investments in entrepreneurial ventures located in seven European countries reveal that 65.7% of these investments were syndicated (see (Bertoni et al., 2013).

backed entrepreneurial ventures were found to exhibit superior innovative and post-IPO operating performances. They also exhibit lower underpricing and higher market valuation at IPO, in accordance with the view that syndication also conveys a stronger signal to uninformed external parties about the quality of the focal entrepreneurial venture.

Investments in OSS entrepreneurial ventures are more risky than in proprietary software entrepreneurial ventures, because of the greater uncertainty inherent in the OSS business model. Hence, we expect VC investors to be more prone to resort to syndication when investing in OSS ventures than in proprietary software ventures so as to diversify investment risk. We also expect OSS ventures to be more inclined to accept an offer made by a VC syndicate than by a standalone VC investor. As OSS entrepreneurial ventures face difficult managerial challenges, the superior ability of VC syndicate members to jointly add value to portfolio firms will be more beneficial to these firms than to their proprietary software counterparts. In addition, as OSS entrepreneurial ventures lack legitimacy, the stronger quality signal conveyed to uninformed external parties by a VC syndicate is especially valuable for these firms. Hence, we derive the following hypothesis:

H2b:VC investments in OSS entrepreneurial ventures will exibit higher degree of syndication than VC investments in proprietary software entrepreneurial ventures.

1.3.DATA AND METHODOLOGY

1.3.1. DATA

To build the sample of firms analyzed in the present paper, we first considered VC-backed software entrepreneurial ventures[16] included in the SDC Platinum (former VentureXpert) database which met the following criteria: i) they were located in the North

[16] Our sample does not include entrepreneurial ventures which did not receive VC. Indeed, we do not study whether OSS entrepreneurial ventures are more or less likely to attract VC investments than their proprietary software counterparts. Rather we focus our analysis on the quality of the VC investors which are attracted by OSS entrepreneurial ventures and the governance of their VC investments, conditional on having obtained VC.

America (USA and Canada); ii) they received their first round of VC investment in the period 1994-2008, and iii) they were 10 years old or younger at the time of the first VC round. 4336 companies met these three criteria.

In order to detect OSS entrepreneurial ventures, we resorted to three different sources. First, following O'Mahony (2002) and Dahlander (2007), we examined the business descriptions provided by VentureXpert. 14 ventures turned out to have adopted an OSS business model. We identify these ventures by searching for the words "open source" in the business description and after reading it, the ones that clearly referred to entrepreneurial ventures developing OSS were labeled as OSS entrepreneurial ventures. Second, we added to this group the 67 entrepreneurial ventures that were mentioned in "The 451 group" reports (Aslett, 2009; Aslett, 2010) as OSS ventures. Aslett (2009, 2010) provide an insight about OSS entrepreneurial ventures which were able to receive VC investment in the period of 1997-2010. Among approximately 130 ventures mentioned in the reports, we were able to identify 67 of them which are included in the sample extracted from SDC. In this sample, 11 ventures were mentioned also in VentureXpert. Third, in accordance with the procedure used by (Fosfuri et al., 2008), we extracted from the Gale Group PROMT and ASAP databases all articles about new product announcements[17] that met the following criteria: i) the article was published in the period 1994-2011, ii) it referred to the SIC code 7372 (software), and iii) it included one or more of the following words: "Open source", "OSS", "FLOSS (free libre open source software)", "Linux", "Apache", or "free software". We extracted about 1500 product announcements. In order to classify a product announcement as relating to an OSS company, all of the extracted announcements were carefully read by a trained research assistant and checked by one of the authors (Appendix 1 shows examples of the product announcements).

[17] In order to detect whether an article was about a new product announcement, we checked whether the following words were included in the article: "product announcement", "product introduction","product/service review", and "software evaluation".

In this way, we selected 54 additional companies. Altogether, we identified 124 OSS companies.[18] This group includes entrepreneurial ventures which received scholarly and public attention such as SugarCRM, Red Hat Inc, JasperSoft Corporation, and SpikeSource, Inc.

In order to build a control group composed of proprietary software entrepreneurial ventures, we considered all software product announcements extracted from the Gale Group PROMT and ASAP databases which met the above mentioned criteria. Then we searched in these documents for the name of the remaining 4,212 VentureXpert companies while excluding the 124 companies identified as OSS companies. To be sure these ventures do not have any OSS product we manually read the documents. In this way, we were able to identify 390 proprietary software entrepreneurial ventures[19].

The final sample includes 514 software entrepreneurial ventures which received VC investment from 1,035 unique VC firms. The analysis is at the dyad level. We consider the 6,555 dyads that correspond to an investment by VC firm *i* in an entrepreneurial venture *j*[20]. 2,029 of these dyads refer to OSS entrepreneurial ventures while the remaining 4,526 refer to proprietary software entrepreneurial ventures.

1.3.2. Dependent Variables

VC quality. The quality of VC firms is quite heterogeneous (Sorensen, 2007), with some VC firms having better screening, monitoring, and coaching ability because of greater

[18] This sample is larger than those used by prior studies that focused on OSS entrepreneurial ventures. For instance, (Wen, Ceccagnoli, & forman, 2012) identified 85 OSS companies and Dahlander (2007) 67 OSS companies.

[19] To be sure they are proprietary we also read their business description provided by VentureXpert.

[20] One might argue that our result can be driven by the fact that a VC can invest several times in an entrepreneurial venture. To control that this is not affecting our results we limit our sample to observations which denote the first time a VC invested in an entrepreneurial venture. The results are qualitatively similar.

investment experience. Accordingly, the first set of dependent variables measures the quality of VC investors through several proxies of their investment experience. [21]

General experience$_{ij}$ is the cumulative number of rounds of investments in which VC firm *i* was involved prior to the investment in portfolio company *j* since 1980[22]. Since each VC round involves interaction with and evaluation of entrepreneurial ventures, in each round VC firms acquire knowledge and expertise regarding different aspects of the VC market and factors influencing success or failure of portfolio companies. This valuable knowledge and expertise has a direct positive impact on the screening, monitoring and coaching ability of the VC firm (Hsu, 2006). In addition to learning, while participating in more rounds VC firms gain access to a larger network of potential suppliers, customers and executives, which in turn can be helpful to their portfolio companies (Sorensen, 2007).

Industry experience$_{ij}$ is the ratio of the cumulative number of VC rounds in information technology entrepreneurial ventures in which VC firm *i* was involved to the total number of its VC rounds prior to the investment in portfolio company *j*. It captures the specialization of VC firms in information technology sector.

IPO experience$_{ij}$ measures the number of rounds the focal VC firm invested in entrepreneurial ventures which went public. An IPO is considered as the most successful exit for VC investments (Sorensen, 2007; Brander et al., 2002). So this variable reflects the ability

[21] There are alternative measures of experience such as age of the VC firm and the number of companies in which VC firms invested (Gompers, 1996; Hochberg et al., 2007). Following Sorensen (2007) we do not consider these variables since for example age does not differentiate between active and inactive investors. Similarly number of companies can be misleading since investments can happen in early stage or late stage. While VC firms which enter in early stages and help ventures to grow gain experiences which can be more relevant in value-added service to the future investments in comparison to VCs which invest in the late stage. VCs that enter in the early stage participate in more investment rounds. Hence, considering number of companies VC invested in, cannot distinguish between VCs which invest from the early stage and VCs that invest only in the late stages.

[22] In order to calculate the general experience, industry specialization and IPO experience, we limited the sample to after 1980. Since till late 70s the VC market was very small and by change in policy at 1979, in which the U.S. Department of Labor clarified the “prudent man” stipulation in the Employment Retirement Income Security Act to allow pension funds to invest in VCs, the VC market grow dramatically (Gompers & Lerner, 2001).

of VC firms to select high quality entrepreneurial ventures and/or to monitor, coach and position them after the investment (Cumming, Haslem, & Knill, 2011).

Capital under management$_{ij}$ is calculated as the logarithm of the total amount invested by VC firm *i* in its portfolio companies in the 5 years prior to the first investment in company *j*. We use this variable as a proxy for the ability of the focal VC firm to attract investment, which in turn is allegedly correlated with performance and reputation of the VC firm.

Connectedness$_{ij}$; it is well known that VC firms often syndicate their investments with other VC firms rather than investing alone, thereby creating a network of investment relationships with other VC firms. Hochberg et al. (2007) have shown that VC firms that enjoy more influential network positions exhibit better performance than other VC firms. *Connectedness*$_{ij}$ measures how well networked VC firm *i* was at the time of its investment in company *j*. For this purpose, we calculated the co-investment relationships VC firm *i* had with other VC firms in the 5 preceding years. For the main analysis, we consider betweeness centrality[23]. Betweeness centrality measures ability of VC to bring VCs with complementary skills together. To make sure data are comparable over time, we normalized this figure by dividing it by the number of possible relationships.

Staging and Syndication. Monitoring of the investment by the VCs is reflected by use of staging and syndication. To capture the risk perception of VC firms regarding the investee entrepreneurial ventures we consider two variables; Number of rounds defined as the total number of VC rounds received by the focal entrepreneurial ventures, with a greater number of rounds being associated with greater perceived risk. Similarly, VC firms enter deal with their peers in order to spread the investment risk, obtain better information on and a more accurate

[23] It is calculated formally, let *pjk* be the proportion of all paths linking actors *j* and *k* that pass through actor *i*. Actor *i*'s *betweenness* is defined as $\Sigma pjk \quad \forall\ i \neq j \neq k$. We also used *Normalized degree of centrality*. The variable determines the number of unique VC firms with which a VC firm has co-invested. Formally, Let *bij* = 1 if at least one syndication relationship exists between VCs *i* and *j*, and zero otherwise. VC *i*'s *degree* then equals $\Sigma j\ bij$ (Hochberg et al., 2007). The results are qualitatively similar. They are not reported in the paper and are available upon request.

evaluation of the investee entrepreneurial venture, and provide it with more added value. We proxy the extent of syndication with the variable Syndication size, defined as the number of VC firms that co-invested in the same round (Lerner, 1994).[24]

1.3.3. INDEPENDENT VARIABLES

The key independent variable in the empirical analysis is a dummy variable that equals 1 if the portfolio company in the focal dyad is an OSS entrepreneurial venture and 0 if it is a proprietary software entrepreneurial venture (OSS).

1.3.4. CONTROL VARIABLES

In the empirical model, we control for characteristics of VC firms, entrepreneurial ventures, investment deal and the general economic environment.

Characteristics of VC firms. A lead VC investor plays a crucial role in VC investment. A lead VC investor takes a more active role than other investors in the interaction with entrepreneurial ventures and makes key decisions (e.g. whether to syndicate). $\textit{Lead investor}_i$ is a dummy variable that equals 1 when VC firm *i* is the lead investor and 0 otherwise. In order to determine who is the lead investor, following previous literature (e.g, Sorenson, 2007) we considered the VC firm that makes the largest total investment in the focal entrepreneurial venture across all VC rounds as the lead investor.

VC firms differ depending on their ownership and governance (e.g. Dimov & Gedajlovic, 2010), which in turn influence their objectives and investment strategies. We controlled for the VC type through 5 dummy variables that indicate that the investor is a private VC, a corporate VC, a bank affiliated VC, an individual (including angel investors) or other VC type.

[24] Some previous studies on syndication measure the size of the syndicate with the number of VC firms that invested in the focal entrepreneurial venture(Sorenson & Stuart 2001; Cumming et al., 2011). For robustness, in this paper we also used this definition of syndicate size (*Syndication size 2*). In addition, we use *Syndication* as dummy variable denoting syndicated investments (Brander et al., 2002). In both cases, the results are similar. For brevity the results are not reported and are available upon request.

Characteristics of entrepreneurial venture. We also control for the stage in which it was at the first round of the investment (*Early stage*). Early stage investments are riskier (Gompers & Lerner, 1999) since entrepreneurial ventures usually lack a financial performance and require large effort to achieve success. The VCs and entrepreneurial ventures tend to cluster in special regions. In the North America majority of VC investments are in California and Massachusetts; hence, we control for geographical location of entrepreneurial ventures by two dummy variables of *California* and Massachusetts which indicate whether they are located in California or Massachusetts. Several studies showed the role of patents in attracting VC investment (e.g. Mann & Sager, 2007). When the information imperfection exists, the patents matter more as signal of quality (Hsu & Ziedonis, 2013). For entrepreneurial ventures *Patent* measures the number of patent applications by entrepreneurial venture *j* prior to the year in which it received the VC investment. Considering the application year instead of the grant year is justified since application is closer to innovation time and patenting procedure can take several months(Hsu & Ziedonis, 2013; Tian & Wang, 2011). We also control for the sub-sector of the software industry in which the entrepreneurial venture *j* operated, based on The North American Industry Classification System (NAICS) provided by VentureXpert. We used three dummy variables which indicate whether entrepreneurial venture primary sub-sector is "Software Publishers", "Software Reproducing", or "Others".

[Table 1-1 about here]

Characteristics of the deal. At the time of the first round of VC investment, information asymmetry is substantially greater than in correspondence with subsequent rounds. Indeed, the receipt of the first VC round gives to uninformed third parties a signal of the good quality of the focal entrepreneurial venture, thereby reducing the extent of the information asymmetries(Li, 2008). *First round*$_{ij}$ is a dummy variable indicating that the focal dyad relates to the first round of funding. We also control for the age of entrepreneurial venture at the time of the VC investment (*Age*)[25]. Information asymmetries between entrepreneurs and investors are greater for younger firms that lack a track record (Sorensen, 2007).

Finally, we consider several variables that reflect general market and macroeconomic conditions. *Number of deals*$_{ij}$ is a proxy for the size of the VC market and *S&P index* controls for public market situation (Cumming et al., 2011). Following Nahata (2008) we resort to two dummy variables to account for the booming information technology market in the period 1998-2000 and the market crash due to the financial crisis in the period 2007-2009. Table 1-1 provides a summary statistics and definition of main variables.

For robustness purpose in order to control for differences in quality of entrepreneurial ventures following (Bengtsson & Hsu, 2010) we examine whether it is favorable for OSS entrepreneurial ventures to exit successfully. We do so by looking at the current status of entrepreneurial venture whether it goes public, bought by other companies, still active or went defunct. IPO is the most successful exit option and provide highest return to investors (Gompers & Lerner, 1999). The second best option is through acquisition. Following prior studies we use a dummy variable equal to one if entrepreneurial venture exited through IPO or were acquired (Gompers & Lerner, 1999; Sorensen, 2007; Nahata, 2008; Tian, 2012).

1.3.5. DESCRIPTIVE STATISTICS

Table 1-2 illustrates descriptive statistics of variables. It also illustrates univariate analysis of differences in the value of the dependent variables between OSS and proprietary software entrepreneurial ventures.

The VC firms which invest in OSS entrepreneurial ventures (Proprietary) on average participated in 414.12 (288.29) prior investment rounds. Similarly, VC firms which invest in

[25] There are some mistakes in the entrepreneurial ventures' founding year as reported by VentureXpert. Whenever we face with companies for which the year of foundation is posterior to the year of the first VC round, we replaced the founding year with the year of the first VC round.

OSS entrepreneurial ventures (Proprietary) on average 79.78 (73.35 %) of prior investments were in information technology. This verifies in general that VC firms are highly specialized in an industry (Gupta, Sapienza 1992).

The average IPO experience of VC firms invested in OSS entrepreneurial ventures (Proprietary) is 88.34 (61.97). Data indicates that VC firms invested in OSS entrepreneurial ventures (Proprietary) on average have 10.52 (9.43) capital under management (in logarithm of total amount invested in the last 5 year). Similarly we can see that VC firms invested in OSS entrepreneurial ventures (Proprietary) on average have 0.61% (0.49%) betweenness centrality. The univariate analysis verifies that quality of VC investors is higher for OSS entrepreneurial ventures. The differences regarding mean and median of both groups (OSS vs. Proprietary) are statistically significant at 1% level.

Regarding monitoring we look at number of rounds and syndication size. VC funding was given to OSS entrepreneurial ventures (Proprietary) in 6.68 (5.83) rounds, while the median is equal to 6 (5) rounds. Both mean and median are significantly different at 1% level. The mean of syndication size in OSS entrepreneurial venture (Proprietary) is 4.72 (4.89). The median of syndication size is 4 for all software entrepreneurial ventures.

For robustness, we we use a dummy variable whether VCs co-invested with at least one peer or invested solely. 92.91% (86.63%) of OSS entrepreneurial ventures (Proprietary) receive VC funding from more than one VC firm. For all software entrepreneurial venture the amount is 88.14%, which is similar to the reported amount by Tian (2012) for all entrepreneurial ventures which exited through IPO.

Regarding control variables, 82% percent of entrepreneurial ventures do not file any patent prior to the first round of investment and 66% of them do not file any patents in all investment rounds. This is slightly lower than what Mann and Sager (2007) showed in the period of 1997-1999, 91% of software entrepreneurial ventures do not file any patent prior the first round of investment. 47.28% of observations belong to entrepreneurial ventures located in California and 16.51% in Massachusetts. Private VCs accounts for 71.45% of observations.

[Table 1-2 about here]

1.3.6. Empirical Methodolody

In this study we focus on impact of collaboration with community of users on VC investment. Respectively, we study quality of VC firms and terms of financing. In all models (j) is referring to entrepreneurial venture, (i) is representing VC firm.

VC quality. In this section we study impact of collaboration with community of users on quality of financing entrepreneurial ventures which they are able to acquire. Our analysis uses the following specification:

$$VCQuality_{ij}=\beta_0+ \beta_1 OSS_j+ B_2 DEAL_{ij}+ B_3 VC_i+ \beta_4 PC_j + \beta_5 Y_t+ \varepsilon_{ij}$$

In this model VCQualityij refers to quality of VC firm (i.e., General experience, Industry specific experience, IPO experience, VC capital under management and connectedness). In this model, we treat General experience, IPO experience and VC capital under management as continuous variables and estimate the model by Ordinary Least Square model (OLS). Since industry specific experience and connectedness can get value between 0 and 100 we are able to treat them as double censored variables. Therefore, we use the Tobit regression model (Long, 1997). $DEAL_{ij}$ includes a series of variables which change through each deal. VC_i is a vector of variables referring to VC firm characteristics and PC_j is a vector of variables referring to entrepreneurial venture characteristics. Y_t is series of macroeconomics variable which can impact VC fund raising, exit and monitoring. Since in our sample we have several observations belonging to an entrepreneurial venture we cluster errors around entrepreneurial ventures.

Staging and syndication. We also look at Monitoring of investment. Since the measures we used are positive integers, we use count models for analyzing monitoring of investment as following:

$$E\left(MON_{ij}\middle|X\right) = \exp\left[\beta_1 . OSS_j + \sum \alpha_i . DEAL_{ij} + \sum \gamma_i . VC_i + \sum \theta_i . PC_j + \sum \delta_i . Y_t\right]$$

In this setting Mon_{ij} is representing two variables of number of rounds which funding was given to entrepreneurial ventures and syndication size. Given there is no high dispersion in our variables, the general assumptions underlying Poisson models, suggesting adopting Poisson model. Alternatively we repeated all models with negative Binomial model in order to test robustness of our results to choice of models. The results are similar. All error terms are clustered around the entrepreneurial venture. Additionally, as an alternative for syndication size we use a dummy variable for existence of more than one VC firm in the deal; therefore we use a Logit model (The results are not reported for brevity and are available upon request). Table 1-3 reports the pair wise correlation of all variables in both models.

[Table 1-3 about here]

1.4.RESULTS

1.4.1. VC QUALITY

Table 1-4 indicates results from OLS and Tobit model which regress measures of VC quality on a dummy variable that represent whether entrepreneurial venture has business model based on open source (OSS). The model also includes variables which control for VC characteristics; five dummy variables indicate whether investor is Private VC, Corporate VC, Bank affiliate VC, Individuals or other type (omitted), in addition to a dummy variable which indicate if VC is lead investor. As well as entrepreneurial venture characteristics, including a dummy indicating first round of investment was early stage (a dummy indicating later stage or expansion stage is omitted), two dummy variable indicating whether entrepreneurial venture is in California or Massachusetts (others is omitted) and three dummy variables indicating the sub-sector of entrepreneurial venture and number of patent application prior funding. We also control for deal characteristics - whether the focal round is the first round of investment and venture age at the focal round of funding. Additionally, we control for macroeconomics variables which can impact VC investment. We include number of VC deals, the return on S&P 500 index, whether year of investment is in information technology bubble (1998-2000) and a dummy for the years of the financial crisis (2007-2009). Models 1-5 in table 1-4 indicate that the OSS entrepreneurial ventures are associated with higher quality VCs, consistent with H1. Higher quality is identified through multiple measures such as general experience (total number of prior deals across all industries), VC's industry specific experience (number of prior deals VC invested in information technology relative to total number of prior deals), IPO experience (number of rounds invested in entrepreneurial venture which went public), capital under management (logarithmic of total amount invested in entrepreneurial ventures) and connectedness (betweenness centrality in syndication network). In model 1 the effect is significant at 10% level, while the effect is significant at 1% level in in models 2, 3, 4 and 5. The results are not only significant statistically but also economically. OSS entrepreneurial ventures receive funding from VC firms which on average have invested in 72.10 more deals which account about 25% more than average general experience of sample. In addition, these VCs make 3.63% more industry specific investments , and have 25.59 more IPO exitsas compared to the mean of sample. When we look at capital under management the coefficient imply that VC firms that invest in OSS entrepreneurial venture have on average 0.56 Million dollars more capital under management and their betweenness centrality is 0.18% more which means they are about 30% more connected relative to the mean of sample.

<u>**[Table 1-4 about here]**</u>

Regarding other variables, we can observe impact of patent on quality of VC firm. This is in line with findings which show impact of intellectual property rights on VC investment (Mann and Sager, 2007; Hsu and Ziedonis, 2013). As expected, lead investors are more experienced. Similarly Private, Bank and Corporate VC are more experienced. Entrepreneurial ventures in California and Massachusetts receive funding from higher quality VCs. In the bubble average quality of VC firms dropped since there was a surge in the number of entrepreneurial ventures , similarly in financial crisis the quality of VC firms increase since business opportunities and fund shrinks and only well respected VCs are able to raise fund and invest.

1.4.2. STAGING AND SYNDICATION

As it was argued above (H2a and H2b), in order to analyze the monitoring of VC investment we use two variables - the number of rounds that the VC invested in the entrepreneurial venture and syndicate size. Since the number of rounds is measured as total number of VC investment the venture received and is not time variant, we limit the analysis to only dyads in the first round of investment. Therefore, the sample drops to 1,177 observations. For the analysis we use count models (Poisson)[26]. Empirical results in model 1 and 2 (Table 1-5) show OSS entrepreneurial ventures receive a greater number of rounds of VC fu nding. Since it was shown that OSS entrepreneurial ventures receive investment from higher quality VCs, one might argue the observed differences can be due to difference in risk tolerance of VCs with different qualities. In order to solve this problem in model 2 we control for VC quality (IPO experience), the results are robust. The coefficients in both models are statistically significant at 1% level. The coefficient in model 1 implies that OSS

[26] For robustness we also consider negative binomial model, the result are robust to choice of econometric model and are available upon request.

entrepreneurial ventures receive VC funding on average in 1.1 more rounds. In general, we find supportive evidence for H2a.

We do not observe significant differences in syndication size between OSS entrepreneurial ventures and proprietary ventures. The Model 3 and 4 (Table 1-5) demonstrates that there are no significant differences among OSS and proprietary ventures. We cannot claim any support for H2b.

[Table 1-5 about here]

The control variables show entrepreneurial ventures that receive VC funding in older age, the numbers of rounds reduce. In software publishing and software reproduction sub sectors the number rounds increase. From model for syndication size we can see more patent applications are associated with larger syndicates. By increase in VC market size syndication size increases.

1.4.3. Robustness Checks

In order to check robustness of our results we run several different alternative analyses. First, there is heterogeneity among OSS entrepreneurial ventures. In order to study the heterogeneity of OSS entrepreneurial ventures we imply two approaches. Primarily, in constructing our sample we used three sources. This allows us to separate OSS entrepreneurial ventures in two different groups. In the first group, we focus on a more conservative definition of the OSS entrepreneurial ventures and consider only entrepreneurial ventures the business model of which is based on open source, as described by VentureXpert or by “The 451 group” reports (i.e. we include only firms identified in steps 1 and 2 of the procedure described above). These firms are denoted by a value equal to 1 of the dummy OSS1. We put the rest of entrepreneurial ventures for which we were able to identify at least one open source product in a separate group (OSS2). While the coefficient in most of models is larger for OSS1 where the venture's business model is entirely based on OSS, a test of difference between coefficients of OSS1 and OSS2 shows there are no statistically significant differences between both groups. Appendix 2 reports the model for quality of VC and monitoring.

Second, Fosfuri et al (2008) shows that endowment of intellectual property of venture impact its decisions on releasing OSS products. Hence, we divided OSS dyads in two groups. The one in which entrepreneurial ventures filed a patent prior to investment (OSS with patent) and the one in which it did not file any patents prior to investment (OSS no patent). Similar to previous robustness check the test of difference shows there is no statistically significant differences between the two groups. Appendix 3 reports the result for VC quality and monitoring.

In the empirical setting we compared the entrepreneurial venture based on whether they develop products in collaboration with a community of users or not. In order to ensure that the non-randomness of the sample does not bias our results, we employ propensity score matching, by using nearest neighbor methodology on VC characteristics (Lead investor, Private, Corporate, and Individual), entrepreneurial venture characteristics (number of patents, age at investment round, geographical location and sub sectors), deal characteristics (First investment) and macroeconomics factors (VC market size, Bubble and Financial crisis). As appendix 4 and 5 depicts the sample size drops to 5,462 observations belonging to 388 entrepreneurial ventures of which 101 are OSS ventures. The results of univariate analysis on matched sample (Appendix 4) confirm that VCs that invest in OSS entrepreneurial ventures are more experienced, consistent with H1, and OSS entrepreneurial ventures receives funding in more rounds and from larger syndicates, consistent with H2a and H2b. The results are statistically significant. After controlling for confounding factors in Appendix 5, we can see that results are qualitatively similar to analysis of the full sample shown in tables 1-4 and 1-5 which show support for H1 and H2a but no support for H2b.

One might argue that there is unobserved heterogeneity in the quality of entrepreneurial ventures. In other words, there are unobserved factors which can impact the quality of VC firms which invest, since higher quality VCs are able to identify better ventures. One of these major factors can be quality of entrepreneurial ventures and the business opportunity they offer. Even though the quality of entrepreneurial ventures is uncertain and hard to evaluate ex-ante, we assume that there are observable factors such as quality of entrepreneurial team, technology, and business opportunity which to some extent can predict the success of entrepreneurial venture. Therefore, following Bengtson and Hsu (2011) we control for quality of entrepreneurial venture, as measured by successful exit, (Merger and acquisition & IPO). The results support H1 and are qualitatively similar. The results are available upon request.

Because selecting to be OSS or proprietary for an entrepreneurial venture is not random, endogeneity may be a potential problem. First, we control for endogeneity by using instrumental variables (Vella & Verbeek 1999) and Heckman treatment model in estimating VC quality (We explain this more formally in appendix 7). In both models we consider a two stage model (control function) where entrepreneurial ventures choose to adopt open source business model or not based on intensity of the individuals with PhD degree in computer science and with hacking abilities in the region. We measure the intensity by dividing number of cyber crimes and PhD graduates in computer science to active work forces in each US state[27]. The logic here is the driving forces of open source entrepreneurial ventures are highly skilled individuals in programming and software development. We resort to the idea that the highly skilled programmers can be found among PhD graduates and self educated hackers.

[27] We were not able to find similar information about Canada, therefore we limit our sample to US based entrepreneurial ventures, The sample include 6400 observations (155 observation less than original sample).

The results verify that VCs that invest in OSS entrepreneurial ventures have higher quality and when we control for endogeneity both the size and statistical significance of coefficient are enhanced. Appendix 6 reports the result of instrumental variables and Heckman treatment model for general experience of VCs[28]. The negative and significant coefficient of lambda (λ) implies that there is a negative correlation between unobserved factors in selection equation (error term) and VC quality. Hence, controlling for endogeneity increases the magnitude of the coefficient of the independent variable (having an OSS entrepreneurial venture) .

Alternatively we use a switching regression model. In this model, VC quality is allowed to differ according to whether entrepreneurial venture is OSS or proprietary (Bertschek & Kaiser 2004). Therefore, we resort on two regimes of OSS and proprietary. This is possible by considering a selection model which determines the probability of an entrepreneurial venture to be OSS or proprietary (regime equation)[29]. Switching regression allows us to estimate the VC quality of OSS entrepreneurial ventures if the same ventures were in proprietary regime[30]. The appendix 8 shows conditional distribution of the VC quality (Capital under management). The method allows us to control whether OSS and proprietary entrepreneurial ventures are systematically different[31]. This is possible by using the selectivity terms (inverse Mills ratio) calculated from regime equation (see appendix 9 for the formal description of model). The inverse Mill ratio captures unobservable information. Then we are able to regress VC quality on inverse mills ratio and control variables for OSS and proprietary entrepreneurial ventures separately. Appendix 8a represents conditional distribution of VC quality for OSS entrepreneurial ventures. The solid line represent the kernel density of VC

[28] The results for other variables are not reported for brevity and are available upon request from authors.

[29] Similar to the previous model entrepreneurial ventures choose to adopt open source business model or not based on intensity of the individuals with PhD degree in computer science and with hacking abilities in the region.

[30] Chemmananur et al. (2011) refers to this type of analysis as “what-if” questions.

[31] This procedure is explained in detail in Heckman (1979) and Maddala (1983).

quality of OSS entrepreneurial ventures from OSS regime while the dashed line represent the kernel density of VC quality of OSS entrepreneurial ventures if they were proprietary. Similarly in the appendix 8b we observe VC quality for proprietary entrepreneurial ventures. The solid line represent the kernel density of VC quality of proprietary entrepreneurial ventures from proprietary regime while the dashed line represent the kernel density of VC quality of proprietary entrepreneurial ventures if they were OSS. Both graphs show changes from OSS to proprietary (Proprietary to OSS) is associated with increase (decrease) in the VC quality.

1.5.CONCLUSION AND DISCUSSION

In this paper, we investigate the impact of a venture's adoption of an open business model on the quality of VCs it receives investments from, and on the staging and syndication patterns of such investment. The main goal of this study was to shed light on substanitial uncertainty related to value captures of open buisiness model and examine how it affects a venture's access to external financing which is necessary for scaling up the business and for venture survival. We focused on OSS business model as a prominent example of open business model and compared it with ventures adopting a proprietary pr closed business model.

We theorized that entrepreneurial ventures that adopts an OSS business model face greater complexity and uncertainty in their system of activities and revenue general model than proprietary ventures. This increases the uncertainty associated with the viability of OSS ventures, with the legitimacy of their business model, and with the potential for financial returns from such models. The challenges associated with OSS business models imply that the ventures that adopt such models will likely benefit much more from the value added services and certification effect that higher quality VCs can provide. We also argued that higher quality VCs have higher risk tolerance and are more likely to invest in OSS entrepreneurial ventures, which are associated with greater uncertainty, than their lower quality peers. We also argued that such VCs are more likely to use risk reduction strategies of staging and syndication.

Based on a sample of 514 software entrepreneurial ventures that received VC funding in 6,555 different deals, we find that software entrepreneurial venture that that adopted an open business models receive funding from higher quality VCs. The result can be driven from two different explanations. First, higher quality VCs possess resources and expertise that can help them tolerate higher risk and help them deal with the complexity of OSS business. Second, higher quality VCs are able to screen more efficiently and are more likely to select higher quality entrepreneurial ventures (Hsu, 2004).

In case of staging, our results show that OSS entrepreneurial ventures on average receive more rounds of VC funding. Staging more frequently allows VCs to monitor entrepreneur efforts and actions, reduces agency cost and reduces downward risk by avoiding inefficient continuation through the exit option. The results can be explained by that the higher risk and complexity associated with investment in OSS entrepreneurial ventures. Higher uncertainty in this case increase likelihood of value of the exit option and consequently lead to more staging (Li, 2008).

We did not find any significant differences in case of syndication size. A possible explanation for observing no differences in syndication size, despite expected higher risk and complexity associated with OSS entrepreneurial ventures, can be that syndication can increase coordination cost and lead to delay in decision making (Gompers & Lerner, 1999) which is more severe for OSS entrepreneurial ventures which have a complex business model. Due to lack of reliance on intellectual property rights, the speed to market is critical for OSS entrepreneurial ventures. Since syndication can cause delay in decision making process, it is possible that VCs are less inclined to syndicate to avoid delay in decision making.

One might argue the result can be biased due to unobserved heterogeneity (for example OSS entrepreneurial ventures are high quality ventures which are able to attract high quality VCs). In order to address this problem we take a number of steps. First, in robustness check we control for the exit as a quality proxy. In addition, we control for endogeneity using Heckman treatment model, instrumental variables and switching regressions. Finally we employ propensity score matching in order to control possible biases in the sample. The results are qualitatively similar.

In this study, we contribute to two streams of literature. First, a growing body of literature has examined open business models, with a special focus on OSS. The initial studies focused on understanding the motivation of contributors (e.g. Lerner & Tirole, 2002; von Hippel & von Krough, 2003; O'Mahony & Ferrero, 2007). Others have examined what determines introduction of open source products by firms (Fosfuri et al., 2008; Wen et al., 2011), the challenges and strategies for benefiting from open source communities (Dahlander & Magnusson, 2005; 2008; West & Gallagher, 2006; Bonaccorsi et al., 2006), and the impact on performance of ventures (Piva et al., 2012; Stam, 2009). However, scholars have rarely explored the financing of firms involving in OSS (see Alexy & George, 2013 for an exception). Our study differs from Alexy and George (2013) in two distinctive features. First while, Alexy and George (2013) focus on adoption of open buisiness model by publicly listed firms, we study entrepreneurial ventures, which are designed on delivering product and services based on open buisiness model. Secondly, in contrary to Alexy and George (2013) that explores the impact of open buisiness model on the market value of firm, we focus on different dimensions of VC investment in OSS entrepreneurial ventures in comparison with proprietary ones. We also contribute to this literature by collecting a unique, and to the best of our knowledge, the most comprehensive dataset on OSS entrepreneurial ventures and by providing some understanding of which VCs invest in such ventures and how. Providing evidence that OSS entrepreneurial ventures are able to attract high quality investors which are crucial for venture success and survival, we offer some evidence that VCs may consider OSS business models as viable business models and despite the associated uncertainty. Moreover, they use risk reduction strategies such as staging to reduce the downward risk of investment.

Second, the paper contributes to the strand of literature that investigates the relationship between entrepreneurial venture's characteristics and VC investment. Mann & Sager (2008), Hsu & Ziedonis (2008), and Engel & Keilbach (2007) study the role of patents on valuation of entrepreneurial ventures, the propensity of receiving VC financing, the terms of financing and return on investment measured by exit status. Hellmann and Puri (2000) focused on product market strategy and dffrentiated between innovator entrepreneurial ventures and imitator ones. Davila et al. (2003) studied the interaction between employee growth of entrepreneurial ventures and VC financing. Hsu (2007) looks at entrepreneur experience and education. Cumming et al (2011) studied the impact of litigation on VC investment. Empirical studies treat entrepreneurial venture homogenous regarding their business models. We contribute to this studies by focusing on different business models (open VS. closed) of entrepreneurial ventures and its impact on VC financing. We focus on uncertainty and complexity associated with OSS business model and investigate its interaction with quality of investors, staging and syndication. Prior literature has highlighted the role of uncertainty in importance of VC quality, staging and syndication. It has shown that when the uncertainty about business prospects increases the value added services and certification effect of higher quality VCs play important role in success and survival of venture (Timmons, Bygrave 1986, Sapienza, Timmons 1989, Sapienza 1992, Hellmann, Puri

2000, Tian, Wang 2011). Consequently higher quality VC are more likely to invest in more uncertain business and industries (Petkova, Wadhwa et al. 2013) not only because they can add more value but also because they have higher risk tolerance (Tian, Wang 2011). In line with this argument we argued that because of the exacerbated uncertainty surrounding OSS business models, conditional on receiving VC financing, the quality of VC investors that such ventures receive financing from, is higher than quality of VCs that invest in proprietary software entrepreneurial ventures. Similarly, some shcolars have argued that the value of staging is positively correlated with uncertainty about the prospect of business (Gompers, 1995; Li, 2008; Tian, 2011). We contribute to this literature by showing higher uncertainty associated with OSS business model increase value of staging and lead to more frequent staging in comparison with proprietary ventures.

The paper has several limitations that could be addressed in future research. First, even though we were able to identify OSS entrepreneurial ventures based on their business descriptions and participation in open source software projects, there is a large variance in business models used by these OSS entrepreneurial ventures. By growing number of OSS entrepreneurial ventures, one might study relationship between VC investment and different business models.In addition, in utilizing communities firms can apply different strategies, for example Dahlander (2007) showed entrepreneurial venture can utilize existing communities or initiate a new community. Moreover, the entrepreneurial ventures can be categorized based on level of activity in community. The future study can identify different categories of community collaboration and evaluate whether investors differentiate between them or not. Second, in this study we only focused on quality of VC investment, staging, and syndication. Future studies can examine the impact of VC investment on the performance of OSS entrepreneurial ventures in comparison with proprietary ones. because of differences in system of activities and reveue generation model of OSS entrepreneurial ventures and proprietary business models, they face difference managerial challenges and uncertainties. The way that VC add value to these ventures might differ and eventually impact venture performance. Third, we focused on one industry (Sofware). It would be also interesting to study open business models by looking at a different industry with a similar setting. Finally, we used VC quality at the level of the VC firm - as (Petkova et al., 2013) noted we do not account for the quality of investors at the individual level. It is possible that an experienced partner leaves an established VC firm and joins a new one. In this case we consider the new VC firm as a lower quality firm even though its founding investor is an experienced and high quality individual. Future studies can focus on individual investors and study role of uncertainty on their investment decisions.

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1.7.TABLES:

Table 1-1- Summary Statistics and Variable Definitions

	Dependent variables		**N**	**Mean**	**Std. dev**	**Min**	**Max**
	VC quality						
VC's general experience	Number of investments in all industries prior funding date	VentureXpert	5465	328.67	547.91	0	6663
VC's industry specific experience	Number of deal VC invested in information technology relative to total number of investments prior funding date (in percentage)	VentureXpert	5465	75.41	22.87	0	100
IPO experience	number of rounds invested in entrepreneurial venture which went public	VentureXpert	5465	70.43	132.55	0	908
Capital under management (log)	Logarithmic of total amount VC invested in entrepreneurial venture in the 5 years prior investment date ($ Thousands)	VentureXpert	5462	9.78	4.42	0	16.63
Connectedness	Between centrality in syndication network of preceding 5 years.		5465	0.53	1.23	0	11.09
	Monitoring						
Number of funding rounds	The number of round entrepreneurial venture received VC funding	VentureXpert	1177	4.09	2.74	1	18
Syndication size	The number of VC firms co-invested at the same deal in an entrepreneurial venture	VentureXpert	6555	4.84	3.17	1	18
	Independent Variable						
OSS	A dummy=1 if entrepreneurial venture has an open source product or its business model is entirely based on open source	Promt, ASAP, VentureXpert and "Open to Invest"	6555	0.31	.46	0	1
	Control Variables						
	VC characteristics						
Lead investor	A dummy=1 if VC firm made largest amount of funding across all rounds in entrepreneurial venture	VentureXpert	6555	0.27	0.44	0	1
VC type	five dummy variables which indicates whether VC is a Private VC, Corporate VC, Bank Affiliated VC, Individuals or Others	VentureXpert					
	Entrepreneurial Venture Characteristics						
Early stage	A dummy=1 if first round of VC funding is in seed or early stage	VentureXpert	6555	0.78	0.41	0	1
California	A dummy variables indicating entrepreneurial venture is in California	VentureXpert	6555	0.47	0.50	0	1
Massachusetts	A dummy variables indicating entrepreneurial venture is in Massachusetts	VentureXpert	6555	0.16	0.37	0	1
Sub-sector	Three dummy variables indicating whether entrepreneurial venture primary sub-sector is "Software Publishers" or "Software Reproducing" or "others".	VentureXpert					
Patents	The cumulative number of patent application	EPO.org	6555	1.82	5.98	0	70

	prior to funding year						
	Deal Characteristics						
First round	A dummy=1 if it is first round of VC funding	VentureXpert	6555	0.18	0.38	0	1
Company age	Investment date- entrepreneurial venture founding year	VentureXpert	6555	4.07	2.98	0	21
	Macroeconomics conditions						
VC market size	Logarithmic number of VC deals in time of funding	VentureXpert	6555	10.12	0.38	8.76	10.72
S&P index	The rerun on S&P 500 index	Standard & Poor	6555	0.14	0.19	-0.37	0.37
Bubble	A dummy=1 if year of funding is 1999-2000		6555	0.32	0.47	0	1
Crisis	A dummy=1 if year of funding is 2007-2009		6555	0.23	0.42	0	1

Table 1-2- Differences in VC quality and VC monitoring of OSS and Proprietary entrepreneurial ventures.

Variable	N	Mean	Median	Test of equality (P-Value)	
				Mean	Median
VC experience					
All PC	5465	328.67	124		
OSS	1754	414.12	169	0.00	0.00
Proprietary	3711	288.29	105		
VC's industry specific experience (%)					
All PC	5465	75.41	80.47		
OSS	1754	79.78	85.75	0.00	0.00
Proprietary	3711	73.35	76.99		
IPO experience					
All PC	5465	70.433	15		
OSS	1754	88.34	16	0.00	0.00
Proprietary	3711	61.97	14		
Capital under management (Log)					
All PC	5465	9.783			
OSS	1754	10.52		0.00	
Proprietary	3711	9.43			
Connectedness (%)					
All PC	5465	0. 53	0.15		
OSS	1754	0. 61	0.17	0.00	0.00
Proprietary	3711	0.49	0.14		
Number of funding rounds					
All PC	6555	6.10	6		
OSS	2029	6.68	6	0.00	0.00
Proprietary	4526	5.83	5		
Syndication size					
All PC	6,555	4.84	4		
OSS	2029	4.72	4	0.04	0.83
Proprietary	4,526	4.89	4		

Table 1-3-Pair wise Correlation Matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23
1- General experience	1.00																						
2-Industry Specific experience	-0.13	1.00																					
3-IPO experience	0.84	-0.11	1.00																				
4-Capital under management	0.42	0.08	0.39	1.00																			
5-Connectedness	0.55	-0.05	0.57	0.29	1.00																		
6-Rounds	0.05	0.03	-0.01	0.10	-0.02	1.00																	
7-Syndication size	-0.04	0.03	-0.02	-0.03	0.02	0.03	1.00																
8-OSS	0.11	0.13	0.09	0.12	0.05	0.12	-0.02	1.00															
9-Lead investor	0.14	-0.02	0.15	0.16	0.00	-0.12	-0.25	-0.01	1.00														
10-Private VC	0.01	0.04	0.04	0.12	-0.21	0.02	-0.13	-0.03	0.14	1.00													
11-Corporate VC	-0.10	0.15	-0.12	-0.13	0.14	-0.01	0.11	0.04	-0.13	-0.63	1.00												
12-Bank VC	0.15	-0.15	0.12	0.03	0.21	0.00	0.08	0.01	-0.05	-0.58	-0.09	1.00											
13-Individual VC	-0.03	-0.01	-0.03	-0.03	-0.02	0.00	0.00	0.00	-0.01	-0.11	-0.02	-0.02	1.00										
14-Company age	0.05	0.03	-0.01	0.13	-0.02	0.28	-0.03	0.05	-0.01	0.04	-0.04	0.00	0.00	1.00									
15-California	0.05	0.10	0.09	0.07	0.03	0.02	0.05	0.12	-0.04	0.01	0.06	-0.05	0.03	-0.05	1.00								
16-Massachussets	-0.04	0.02	-0.05	0.04	0.01	0.04	-0.02	-0.02	0.04	0.03	-0.03	0.00	-0.02	0.03	-0.43	1.00							
17-Soft publishing	0.07	0.06	0.00	0.10	-0.03	0.11	-0.06	0.15	0.02	0.01	-0.01	0.00	-0.01	0.09	0.04	0.03	1.00						
18-Soft reproduction	-0.09	-0.03	-0.04	-0.06	0.02	-0.05	0.04	-0.20	-0.05	0.00	0.00	0.01	0.02	-0.04	-0.07	0.14	-0.58	1.00					
19-Patents	0.14	-0.01	0.09	0.06	0.05	0.10	0.09	-0.01	-0.05	-0.01	0.02	0.01	0.00	0.18	-0.02	-0.08	-0.04	-0.11	1.00				
20-First investment	-0.04	-0.08	-0.02	-0.13	0.00	-0.29	-0.23	-0.06	0.12	0.04	-0.04	-0.03	0.00	-0.31	-0.03	-0.04	-0.03	-0.01	-0.10	1.00			
21-Early stage	0.03	0.09	0.00	0.05	-0.03	0.10	0.06	0.13	-0.08	0.03	-0.02	-0.02	-0.04	-0.15	0.05	0.11	0.10	-0.02	-0.06	-0.08	1.00		
22-VC market size	0.01	0.10	-0.01	0.04	-0.03	0.04	0.19	0.04	0.00	-0.12	0.08	0.06	-0.01	0.10	-0.01	0.00	0.10	-0.22	0.05	-0.14	-0.02	1.00	
23-S & P index	-0.06	-0.11	-0.01	-0.07	0.06	0.09	0.09	-0.27	-0.07	-0.07	0.04	0.06	0.02	-0.10	-0.03	0.16	-0.18	0.27	-0.02	-0.09	0.02	-0.13	1.0
24-Bubble	-0.09	-0.03	-0.03	-0.14	0.04	-0.14	0.22	-0.19	-0.04	-0.14	0.11	0.08	-0.01	-0.20	-0.02	0.00	-0.12	0.05	-0.02	0.04	-0.07	0.59	0.2
25- Fin crisis	0.16	0.09	0.05	0.16	-0.03	0.16	-0.10	0.25	0.05	0.08	-0.04	-0.05	-0.01	0.32	0.08	-0.03	0.24	-0.27	0.12	-0.16	0.11	0.07	-0.

Table 1-4-VC quality regression

	General experience (OLS)	Industry Specific experience(%) (Tobit)	IPO experience (OLS)	Capital under management(log) (OLS)	Normalized Betweeness Centrality(%) (Tobit)
OSS	72.095	3.637	25.588	0.562	0.180
	(41.205)*	(1.528)**	(10.297)**	(0.217)***	(0.063)***
Lead investor	171.607	-1.254	42.522	1.529	0.137
	(32.937)***	(1.236)	(9.135)***	(0.176)***	(0.050)***
Private VC	204.906	11.918	53.435	2.727	0.381
	(22.716)***	(3.685)***	(5.611)***	(0.408)***	(0.056)***
Corporate VC	62.182	24.539	2.916	0.964	0.964
	(27.789)**	(4.355)***	(5.198)	(0.481)**	(0.169)***
Bank VC	519.479	-1.210	110.967	3.250	1.436
	(128.630)***	(4.647)	(15.156)***	(0.537)***	(0.208)***
Individual VC	-64.960	4.338	-20.498	0.055	-0.023
	(41.227)	(9.400)	(11.012)*	(0.950)	(0.121)
Early stage	15.305	3.572	-3.550	0.282	-0.079
	(32.050)	(1.569)**	(8.553)	(0.233)	(0.067)
California	46.530	4.707	21.347	0.777	0.135
	(36.507)	(1.619)***	(9.254)**	(0.200)***	(0.060)**
Massachussets	-27.580	3.717	-5.643	0.661	0.161
	(43.251)	(1.921)*	(10.430)	(0.272)**	(0.080)**
Soft publishing	22.856	1.404	-4.564	0.473	-0.008
	(39.635)	(1.621)	(10.203)	(0.211)**	(0.063)
Soft reproduction	-16.918	2.841	-4.100	0.316	0.001
	(34.533)	(1.905)	(9.831)	(0.245)	(0.070)
Patents	12.416	-0.021	2.341	0.042	0.011
	(3.889)***	(0.122)	(0.797)***	(0.015)***	(0.005)**
First investment	-36.409	-2.766	-9.340	-1.101	-0.069
	(19.025)*	(1.255)**	(5.232)*	(0.186)***	(0.049)
Company age	-6.369	-0.060	-1.830	0.055	0.005

	(4.930)	(0.176)	(1.181)	(0.033)*	(0.008)
VC market size	39.525	7.862	-3.099	1.413	-0.316
	(34.189)	(1.937)***	(9.213)	(0.305)***	(0.079)***
S & P index	47.483	-10.225	22.559	0.362	0.203
	(87.719)	(3.712)***	(23.554)	(0.497)	(0.161)
Bubble	-79.652	-3.390	-1.386	-1.547	0.166
	(35.201)**	(1.728)**	(8.734)	(0.269)***	(0.073)**
Fin crisis	136.267	-0.418	7.676	0.384	0.032
	(44.778)***	(1.413)	(9.131)	(0.197)*	(0.053)
Constant	-399.397	-19.146	26.463	-8.573	
	(340.779)	(19.637)	(91.707)	(3.025)***	
sigma		24.910			1.249
		(0.681)***			(0.067)***
R2	0.11		0.08	0.12	
N	5,465	5,465	5,465	5,462	5,465

Note. In all models clustered Robust Std. Err. Is Reported in parentheses, *, ** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively

Table 1-5- VC monitoring Poisson regression

	rounds	rounds	syndication size	syndication size
	1	2	3	4
OSS	0.248	0.243	-0.020	0.001
	(0.072)***	(0.077)***	(0.072)	(0.066)
Lead investor	-0.389	-0.359	-0.301	-0.312
	(0.046)***	(0.050)***	(0.030)***	(0.033)***
Private VC	0.109	0.130	0.176	0.014
	(0.052)**	(0.102)	(0.056)***	(0.054)
Corporate VC	-0.041	0.052	0.305	0.109
	(0.100)	(0.136)	(0.051)***	(0.073)
Bank VC	-0.017	-0.032	0.275	0.121
	(0.113)	(0.153)	(0.058)***	(0.068)*
Individual VC	-0.062	0.280	0.178	0.091
	(0.074)	(0.233)	(0.081)**	(0.194)
Early stage	0.025	0.108	0.102	0.081
	(0.078)	(0.082)	(0.066)	(0.066)
California	0.075	0.066	0.033	0.051
	(0.070)	(0.072)	(0.076)	(0.069)
Massachussets	0.244	0.208	-0.017	-0.003
	(0.091)***	(0.092)**	(0.085)	(0.076)
Soft publishing	0.176	0.181	-0.031	-0.030
	(0.077)**	(0.081)**	(0.082)	(0.079)
Soft reproduction	0.130	0.181	0.015	0.019
	(0.085)	(0.092)**	(0.078)	(0.078)
Patents	-0.007	-0.009	0.007	0.007
	(0.012)	(0.016)	(0.003)**	(0.003)**
First investment			-0.458	-0.442
			(0.050)***	(0.046)***
Company age	-0.050	-0.045	-0.013	-0.012
	(0.018)***	(0.018)**	(0.010)	(0.009)
VC market size	0.028	0.026	0.183	0.174
	(0.113)	(0.126)	(0.093)**	(0.093)*
S & P index	0.356	0.311	-0.009	-0.028
	(0.204)*	(0.219)	(0.134)	(0.134)
Bubble	-0.051	-0.039	0.144	0.163
	(0.103)	(0.108)	(0.081)*	(0.083)**
Fin crisis	-0.100	-0.100	-0.089	-0.124
	(0.107)	(0.107)	(0.096)	(0.070)*
IPO exprience		0.000		0.000
		(0.000)		
Constant	0.990	0.905	-0.387	-0.145
	(1.127)	(1.281)	(0.892)	(0.918)
N	1,177	898	6,555	5,465

Note. In all models clustered Robust Std. Err. Is Reported in parentheses, * ,** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively.

1.8.APPENDICES:

Appendix 1: two examples of OSS product announcements extracted from PROMT

eWeek, May 19, 2003 pNA

Crossover 2.0 Lets Linux Run More Windows Apps. (from CodeWeaver)(Brief Article)

Full Text: COPYRIGHT 2003 Ziff Davis Media Inc.

As the de facto standard in desktop operating systems, Windows is generally the platform of choice--often to the exclusion of others--for commercially developed applications, including many upon which companies rely heavily.

Although good open-source alternatives to Windows-only applications have been appearing in growing numbers, sometimes only the Windows version will do.

CodeWeavers Inc.'s CrossOver Office 2.0, which shipped last month, enables Linux users to run certain Windows native applications, most notably Adobe Systems Inc.'s Photoshop, IBM's Lotus Software division's Notes and Microsoft Corp.'s Office XP (including Microsoft's Access, which the previous version of CrossOver Office did not support).

CrossOver Office, which is priced at $55, is based on Wine, an open-source Windows API implementation that enables Linux users to run many applications developed for Windows.

Core Security Readies Web App Security Tool: Core Security Technologies applications

Full Text: COPYRIGHT 2007 Ziff Davis Media Inc.

Core Security Technologies is unveiling an open-source tool called Core Grasp Aug. 2, which is aimed at protecting Web applications from attack.

Appendix 2-Robustness Check by differentiating between OSS entrepreneurial ventures which their business model is entirely based on OSS (OSS1) and entrepreneurial venture we found only one OSS release (OSS2)

	Industry Specific experience(%)	General experience	IPO experience	Capital under management(log)	Normalized Betweeness Centrality(%)	rounds	syndication size
OSS1	3.024	108.314	30.336	0.888	0.222	0.321	-0.097
	(1.589)*	(59.251)*	(15.317)**	(0.269)***	(0.077)***	(0.089)***	(0.103)
OSS2	4.212	36.155	20.876	0.239	0.093	0.185	0.131
	(1.695)**	(45.893)	(12.132)*	(0.278)	(0.077)	(0.094)**	(0.076)*
Lead investor	-0.668	171.077	42.452	1.524	0.094	-0.393	-0.291
	(1.109)	(32.745)***	(9.101)***	(0.175)***	(0.047)**	(0.046)***	(0.025)***
Private VC	11.995	201.065	52.932	2.692	0.243	0.107	0.039
	(3.139)***	(22.206)***	(5.561)***	(0.411)***	(0.028)***	(0.052)**	(0.052)
Corporate VC	21.496	57.510	2.304	0.921	0.899	-0.036	0.116
	(3.646)***	(26.976)**	(5.122)	(0.480)*	(0.149)***	(0.100)	(0.042)***
Bank VC	-0.458	519.627	110.986	3.251	1.288	-0.003	0.121
	(4.092)	(128.666)***	(15.182)***	(0.542)***	(0.190)***	(0.114)	(0.054)**
Individual VC	6.872	-77.392	-22.128	-0.058	-0.114	-0.060	-0.037
	(8.482)	(44.321)*	(11.636)*	(0.938)	(0.059)*	(0.074)	(0.071)
Patents	-0.026	12.614	2.367	0.044	0.011	-0.007	0.009
	(0.104)	(3.963)***	(0.803)***	(0.016)***	(0.005)**	(0.012)	(0.002)***
Early stage	3.071	16.622	-3.377	0.294	-0.083	0.020	0.138
	(1.402)**	(32.443)	(8.614)	(0.235)	(0.063)	(0.078)	(0.082)*
California	4.797	39.027	20.363	0.710	0.098	0.064	0.108
	(1.427)***	(37.878)	(9.712)**	(0.204)***	(0.057)*	(0.070)	(0.079)
Massachussets	4.207	-30.131	-5.978	0.638	0.126	0.241	-0.133
	(1.686)**	(43.358)	(10.510)	(0.269)**	(0.074)*	(0.089)***	(0.088)
Soft publishing	1.392	20.836	-4.829	0.455	-0.039	0.179	-0.008
	(1.412)	(39.684)	(10.149)	(0.213)**	(0.059)	(0.078)**	(0.090)
Soft reproduction	2.646	-19.849	-4.484	0.289	-0.025	0.131	0.010
	(1.648)	(34.097)	(9.699)	(0.243)	(0.065)	(0.086)	(0.098)
First investment	-2.668	-38.314	-9.590	-1.118	0.004		-0.264

	(1.073)**	(18.991)**	(5.223)*	(0.185)***	(0.043)		(0.032)***
Company age	-0.054	-5.889	-1.767	0.059	0.003	-0.049	0.003
	(0.164)	(5.008)	(1.198)	(0.033)*	(0.008)	(0.018)***	(0.009)
VC market size	8.219	33.480	-3.891	1.358	-0.362	0.005	0.120
	(1.678)***	(34.630)	(9.285)	(0.303)***	(0.071)***	(0.116)	(0.085)
S & P index	-8.730	49.947	22.882	0.384	0.167	0.352	0.390
	(3.218)***	(88.102)	(23.590)	(0.494)	(0.150)	(0.203)*	(0.124)***
Bubble	-3.679	-73.662	-0.601	-1.493	0.234	-0.022	0.018
	(1.516)**	(35.792)**	(8.775)	(0.268)***	(0.064)***	(0.108)	(0.059)
Fin crisis	0.539	120.955	5.669	0.246	-0.012	-0.127	-0.097
	(1.331)	(45.285)***	(9.275)	(0.205)	(0.050)	(0.109)	(0.101)
Constant	-24.412	-331.681	35.341	-7.963	3.651	1.221	0.831
	(17.034)	(344.689)	(92.285)	(3.005)***	(0.707)***	(1.151)	(0.794)
R2	0.10	0.11	0.08	0.13	0.09		
N	5,465	5,465	5,465	5,462	5,465	1,177	6,555

Note. In all models clustered Robust Std. Err. Is Reported in parentheses, *, ** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively.

Appendix 3- Robustness Check by differentiating between investment dyads belonging to OSS entrepreneurial ventures with patent (OSS with patent) and with no patent (OSS no patent)

	General experience	Industry Specific experience (%)	IPO experience	Capital under management (log)	Normalized Betweeness Centrality (%)	rounds	syndication size
OSS no patent	69.818	4.270	22.945	0.466	0.182	0.224	-0.142
	(44.621)	(1.484)***	(11.649)**	(0.249)*	(0.080)**	(0.074)***	(0.070)**
OSS with patent	74.774	2.892	28.698	0.676	0.178	0.418	0.103
	(53.667)	(2.201)	(13.186)**	(0.264)**	(0.081)**	(0.160)***	(0.089)
Lead investor	171.703	-1.282	42.633	1.533	0.137	-0.390	-0.298
	(33.146)***	(1.233)	(9.188)***	(0.176)***	(0.050)***	(0.046)***	(0.029)***
Private VC	204.936	11.912	53.470	2.729	0.381	0.101	0.171
	(22.744)***	(3.687)***	(5.617)***	(0.408)***	(0.056)***	(0.052)*	(0.056)***
Corporate VC	62.248	24.525	2.994	0.967	0.964	-0.041	0.300
	(27.730)**	(4.356)***	(5.196)	(0.481)**	(0.169)***	(0.100)	(0.052)***
Bank VC	519.321	-1.162	110.784	3.244	1.436	-0.044	0.261
	(129.082)***	(4.647)	(15.208)***	(0.535)***	(0.209)***	(0.105)	(0.058)***
Individual VC	-65.200	4.411	-20.776	0.045	-0.023	-0.069	0.172
	(41.363)	(9.435)	(11.142)*	(0.943)	(0.121)	(0.074)	(0.081)**
Patents	12.378	-0.011	2.297	0.041	0.011	-0.010	0.005
	(3.913)***	(0.125)	(0.796)***	(0.015)***	(0.005)**	(0.016)	(0.003)*
Early stage	15.085	3.632	-3.805	0.273	-0.078	0.027	0.090
	(31.695)	(1.564)**	(8.460)	(0.234)	(0.066)	(0.077)	(0.064)
California	46.508	4.713	21.321	0.776	0.135	0.076	0.033
	(36.521)	(1.620)***	(9.263)**	(0.200)***	(0.061)**	(0.069)	(0.075)
Massachussets	-27.661	3.741	-5.737	0.657	0.161	0.239	-0.020
	(43.216)	(1.921)*	(10.415)	(0.272)**	(0.080)**	(0.089)***	(0.085)
Soft publishing	23.001	1.365	-4.395	0.480	-0.008	0.175	-0.023
	(39.689)	(1.605)	(10.261)	(0.212)**	(0.064)	(0.077)**	(0.079)
Soft reproduction	-16.845	2.822	-4.015	0.319	0.001	0.129	0.018
	(34.650)	(1.897)	(9.897)	(0.245)	(0.070)	(0.085)	(0.076)
First investment	-36.143	-2.840	-9.031	-1.090	-0.069		-0.445

	(18.943)*	(1.248)**	(5.200)*	(0.187)***	(0.049)		(0.050)***
Company age	-6.441	-0.039	-1.913	0.052	0.005	-0.049	-0.017
	(5.036)	(0.179)	(1.223)	(0.034)	(0.008)	(0.018)***	(0.010)*
VC market size	39.705	7.811	-2.890	1.420	-0.316	0.030	0.187
	(34.515)	(1.942)***	(9.277)	(0.306)***	(0.079)***	(0.112)	(0.092)**
S & P index	47.338	-10.188	22.391	0.356	0.203	0.358	-0.017
	(87.920)	(3.712)***	(23.642)	(0.498)	(0.161)	(0.204)*	(0.131)
Bubble	-79.645	-3.392	-1.377	-1.547	0.166	-0.052	0.148
	(35.217)**	(1.733)*	(8.763)	(0.269)***	(0.073)**	(0.103)	(0.079)*
Fin crisis	136.443	-0.469	7.881	0.391	0.032	-0.101	-0.079
	(44.323)***	(1.402)	(9.011)	(0.197)**	(0.053)	(0.108)	(0.094)
Sigma		24.906			1.249		
		(0.682)***			(0.067)***		
_cons	-400.846	-18.735	24.781	-8.635	2.920	0.979	-0.397
	(343.445)	(19.632)	(92.218)	(3.032)***	(0.794)***	(1.114)	(0.886)
R2	0.11		0.08	0.12			
N	5,465	5,465	5,465	5,462	5,465	1,177	6,555

Note. In all models clustered Robust Std. Err. Is Reported in parentheses, * ,** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively

Appendix 4 - univariate analysis after propensity score matching

Outcome	Expected sign	OSS	Proprietary	Differences	Std. Error	t-stat
General experience	+	414.31	360.87	53.437***	26.05	2.05
Industry specific experience	+	79.80	75.28	4.51***	1.00	4.50
IPO experience	+	88.39	71.38	17.01***	5.94	2.86
Capital under management	+	10.52	9.62	0.90**	.19	4.72
Connectedness	+	0.61	.51	0.10*	0.05	1.73
# Rounds	+	6.74	5.91	0.82***	0.13	6.32
Syndication size	I	4.71	4.21	0.51***	.12	4.30

Note. *, ** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively

Appendix 5 –regression of VC quality and monitoring after Propensity Score matching

	General experience	Industry Specific experience(%)	IPO experience	Capital under management (log)	Normalized Betweeness Centrality(%)	rounds	syndication size
OSS	72.375	3.637	25.659	0.562	0.181	0.249	0.003
	(41.213)*	(1.528)**	(10.305)**	(0.217)***	(0.063)***	(0.076)***	(0.066)
Lead investor	171.528	-1.256	42.506	1.529	0.136	-0.355	-0.311
	(32.929)***	(1.235)	(9.133)***	(0.176)***	(0.050)***	(0.050)***	(0.033)***
Private VC	206.055	12.288	53.503	2.727	0.375	0.139	0.012
	(22.752)***	(3.728)***	(5.626)***	(0.408)***	(0.054)***	(0.102)	(0.054)
Corporate VC	63.285	24.906	2.976	0.964	0.957	0.055	0.105
	(27.856)**	(4.391)***	(5.213)	(0.481)**	(0.169)***	(0.136)	(0.073)
Bank VC	522.002	-0.792	111.352	3.250	1.434	-0.008	0.122
	(128.997)***	(4.686)	(15.184)***	(0.537)***	(0.208)***	(0.148)	(0.069)*
Individual VC	-63.936	4.701	-20.453	0.055	-0.030	0.273	0.087
	(41.278)	(9.422)	(11.031)*	(0.950)	(0.120)	(0.232)	(0.194)
Patents	12.423	-0.019	2.341	0.042	0.011	-0.008	0.007
	(3.888)***	(0.123)	(0.797)***	(0.015)***	(0.005)**	(0.016)	(0.003)**
Early stage	15.548	3.619	-3.519	0.282	-0.079	0.106	0.081
	(32.080)	(1.569)**	(8.558)	(0.233)	(0.067)	(0.082)	(0.066)
California	46.815	4.734	21.402	0.777	0.136	0.070	0.052
	(36.502)	(1.619)***	(9.257)**	(0.200)***	(0.060)**	(0.072)	(0.069)
Massachussets	-27.496	3.764	-5.660	0.661	0.162	0.206	-0.004
	(43.273)	(1.930)*	(10.436)	(0.272)**	(0.080)**	(0.093)**	(0.076)
Soft publishing	23.171	1.437	-4.504	0.473	-0.008	0.179	-0.030
	(39.671)	(1.621)	(10.208)	(0.211)**	(0.063)	(0.081)**	(0.079)
Soft reproduction	-16.740	2.907	-4.100	0.316	0.000	0.176	0.018
	(34.550)	(1.907)	(9.835)	(0.245)	(0.070)	(0.092)*	(0.077)
First investment	-36.336	-2.738	-9.340	-1.101	-0.069	0.000	-0.443
	(19.030)*	(1.254)**	(5.233)*	(0.186)***	(0.049)	(0.000)	(0.046)***

Company age	-6.367	-0.063	-1.827	0.055	0.005	-0.045	-0.012
	(4.933)	(0.176)	(1.182)	(0.033)*	(0.008)	(0.018)**	(0.009)
VC market size	39.997	7.978	-3.064	1.413	-0.315	0.026	0.171
	(34.243)	(1.941)***	(9.227)	(0.305)***	(0.079)***	(0.126)	(0.093)*
S & P index	47.908	-10.204	22.640	0.362	0.207	0.314	-0.029
	(87.788)	(3.717)***	(23.569)	(0.497)	(0.161)	(0.218)	(0.133)
Bubble	-80.320	-3.522	-1.462	-1.547	0.165	-0.043	0.165
	(35.262)**	(1.727)**	(8.749)	(0.269)***	(0.073)**	(0.107)	(0.083)**
Fin crisis	135.830	-0.452	7.592	0.384	0.030	-0.105	-0.123
	(44.740)***	(1.414)	(9.134)	(0.197)*	(0.053)	(0.107)	(0.070)*
Constant	-405.731	-20.737	25.970	-8.573	2.917	0.917	-0.118
	(341.488)	(19.716)	(91.889)	(3.025)***	(0.790)***	(1.281)	(0.917)
Sigma		24.896			1.249		
		(0.681)***			(0.067)***		
R2	0.11		0.08	0.12			
N	5,462	5,462	5,462	5,462	5,462	898	5,462

Note. In all models clustered Robust Std. Err. Is Reported in parentheses, *, ** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively

Appendix 6 – Endogeneity check by using instrumental variables (IV) and Heckman treatment (CF) model (Dependent Variable: VC's general experience)

	Probit selection	IV	CF
OSS			470.484
			(98.456)***
OSS predicted		457.826	
		(96.589)***	
PhD intensity	1.281		
	(0.162)***		
Hacker intensity	0.031		
	(0.004)***		
Lead investor	-0.046	181.134	181.643
	(0.043)	(15.259)***	(15.204)***
Private VC	-0.018	214.835	214.240
	(0.117)	(12.701)***	(40.293)***
Corporate VC	0.323	30.832	29.850
	(0.130)**	(20.634)	(47.675)
Bank VC	0.265	355.565	353.920
	(0.133)**	(40.206)***	(48.135)***
Individual VC	0.330	-77.987	-79.041
	(0.358)	(28.680)***	(129.761)
Early stage	0.392	-37.717	-38.575
	(0.050)***	(18.981)**	(21.128)*
Soft publishing	0.023	5.844	4.764
	(0.048)	(17.789)	(17.151)
Soft reproduction	-0.407	16.464	15.323
	(0.054)***	(20.103)	(20.644)
Patents	-0.006	11.103	11.244
	(0.004)*	(1.768)***	(1.230)***
First investment	-0.218	-29.094	-25.792
	(0.058)***	(18.351)	(20.329)
Company age	-0.003	-3.187	-3.055
	(0.007)	(2.345)	(2.548)
VC market size	-0.149	-10.474	-10.949
	(0.054)***	(3.378)***	(4.931)**
S & P index	-1.599	198.267	209.691
	(0.112)***	(54.777)***	(63.444)***
Fin crisis	0.440	65.718	64.015
	(0.050)***	(27.494)**	(25.678)**
_cons	-0.817		-0.817
	(0.620)		(0.633)
Lambda			-220.293
			(59.004)***
N	5,336	5,336	5,336
R2		0.37	

Note. In all models clustered Robust Std. Err. Is Reported in parentheses, *, ** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively

Appendix 7: Formal description of instrumental variable and Heckman treatment model

In robustness section we used a method to solve for possible endogeneity problem. In this part we try to explain formally how the model works:

We investigate the VC quality (y_{ij}) that entrepreneurial ventures received depending on whether the firm adopted an OSS business model or relied on proprietary model (OSS_j) .

$y_{ij} = \beta_j' \, OSS_j + \beta_{ij}' \, x_j + \varepsilon_{ij}$ *(1)*

where β_{ij}' and β_j' are unknown parameters and ε_{ij} is zero mean error terms .

In this paper following (Vella and Verbek, 1999) we consider OSS_j as treatment variable. This will allow us to estimate equation (1) via instrumental variables and control function approach (CF). In the both cases we estimate selection equation as following:

$OSS_j = \gamma' z_i + u_i$, (2)

Where z_i is a set of variables of whether an entrepreneurial venture choose OSS business model or not. It is enough to include an instrument with nonzero coefficient in the equation (3) and identify the experimental treatment average (Vella and Verbek, 1999). u_i is independent of z_i and normally distributed.

This procedure will allow us to solve endogeneity problem which implies if we estimate equation 1 without correcting for endogeneity ε_{ij} *and* u_i can be correlated and lead to biased estimate of β in equation (1).

In the first approach from equation (2) we estimate predicted probabilities of OSSj in a Probit model and insert Eq. (1). The predicted value of OSSj is correlated with y_{ij} *but not with* ε_{ij} . Hence we can estimate (1) *by OLS.*

$y_{ij} = \beta j \, \widehat{OSS_j} + \beta ij \, xj + \varepsilon ij$ (3)

In the second approach we use control function method (Heckman, 1978, 1979), which can be shown formally as following: let us consider the conditional expectation of y_{ij} *given on* OSS_j and z_i is:

$E(yij| \text{OSSj}, \text{zi}) = \beta j' \, OSSj + \beta ij' \, xj + E(\eta i| \text{OSSj}, \text{zi})$ (4)

Where we have:

$$E(\eta i|\ \text{OSSj}, \text{zi}) = OSSj\ E(\varepsilon ij \mid \text{OSSj} = 1, \text{zi}) + (1 - \text{OSSj})\ E(\varepsilon ij \mid \text{OSSj} = 0, \text{zi}) \quad (4)$$

Under the joint normality assumption, the two conditional expectations on the right side can be written as:

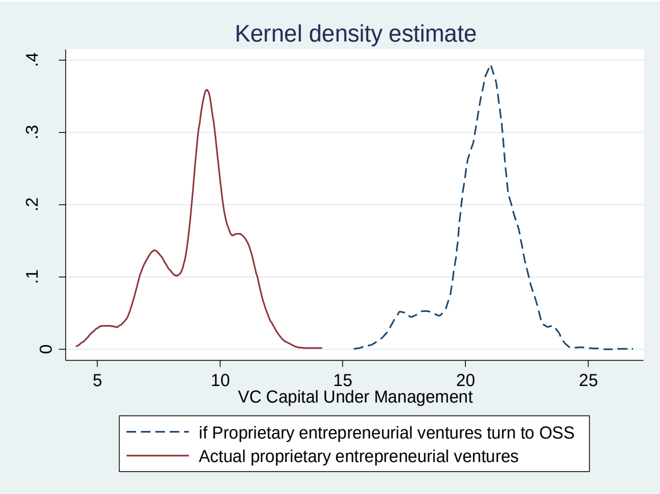
$$E(\varepsilon ij \mid OSSj, zi) = \sigma j\varepsilon\lambda i(zi\pi) \quad (5)$$

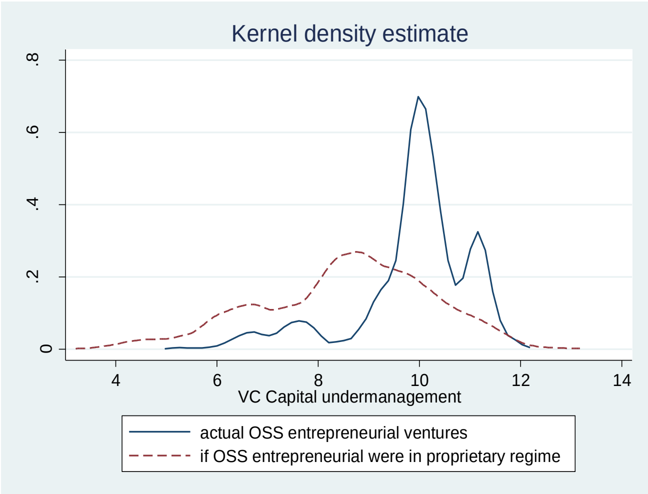
Where

$$\lambda_i(z_i\pi) = OSS_j \frac{\phi(-z_i\pi)}{1-\Phi(-z_i\pi)} + (1 - OSS_j)\frac{-\phi(z_i\pi)}{\Phi(-z_i\pi)} \qquad (6)$$

$\lambda_i(z_i\pi)$ Is generalized residual of the Probit model (see Gourieroux et al, 1987) which describes the treatment decision, where ϕ (.) represents the probability density function and $\Phi(.)$ is cumulative density function. $\lambda_i(z_i\pi)$ will be estimated from equation (6). In the next step we have two options. First we interact estimated $\lambda_i(z_i\pi)$ $(\widehat{\lambda})$ and OSS_j and estimate equation 1. Alternatively we can add $(\widehat{\lambda})$ as a single regressor in equation (1). the second option require an additional assumption that standard deviation of treated and none treated are equal.

Appendix 8a (Graph at right) and 8b (Graph at left): The VC quality in the OSS and proprietary regime





Appendix 8C: Actual and Hypothetical VC quality in the OSS and proprietary regime (dependent variable Capital under management)

	Actual VC quality for OSS entrepreneurial ventures	Hypothetical VC quality for OSS entrepreneurial ventures	difference
Mean	9.89	8.56	1.33***
	Actual VC quality for proprietary entrepreneurial ventures	Hypothetical VC quality for Proprietary entrepreneurial ventures	difference
Mean	9.12	20.71	-11.58***

Note. *, ** or *** indicate statistical significance at the 10%, 5%, 1% level, respectively

Appendix 9: Formal description of "Switching Regression" model

We investigate the VC quality (y_{ij}) that an entrepreneurial venture received depending on whether the firm adopted an OSS business model or relied on proprietary model (OSS_j).

$$y_{ij}= \beta_j^{'} OSS_j + \delta_{ij}^{'} x_j + \varepsilon_{ij} \quad (1)$$

Where $\beta_{ij}^{'}$ and $\beta_j^{'}$ are unknown parameters and ε_{ij} is zero mean error terms.

In this paper following (Bertschek and Kaiser, 2004) we consider two regimes of OSS and proprietary. The VC quality in OSS regime is:

$$y_{i1} = \delta_{i1} x_j + \varepsilon_{i1} \quad if\ OSSj=1 \quad (2)$$

And in proprietary regime is:

$$y_{i0} = \delta_{i0} x_j + \varepsilon_{i0} \quad if\ OSSj=0 \quad (3)$$

Where *1* and *0* refer to where entrepreneurial ventures are OSS or proprietary.

Firm decide to choose OSS model if the cost involved (C_i) is smaller than gain (here VC quality) thus latent variable is:

$$I_i^* = a(yi1 - yi0) - Ci + ui \quad (3)$$

It represents the difference in quality of VC and cost arising from adopting OSS business model, where u_i is an i.i.d normally distributed optimization error. Therefore the selection mechanism for observing OSS business model is:

$$\text{OSSj} = \begin{cases} 1 & if\ I_i^* > 0 \\ 0, & otherwise \end{cases} \quad (4)$$

By substituting Eq. 1 and 2 in Eq. 3 we have:

$$I_i^* = axj\left(\delta i1 - \delta i0\right) - Ci + vi = Zi\pi + vi \quad (5)$$

Where $= a(\varepsilon i1 - \varepsilon i2) + ui$, has a normal distribution on with N $(0,\sigma^2_{ossj})$.This implies we can jointly estimate Eq. 1, 2 and 5 using a full information maximum likelihood estimator. Practically we are able to estimate whether entrepreneurial venture is in OSS or proprietary regime using a Probit model and the likelihood function can be shown as following (Zax, 1999; Maddala 1983):

$$L = \sum_i \left(OSSj \left\{ \ln\left(\Phi(\psi 1i) + \ln\left(\frac{\phi\left(\frac{\varepsilon 1}{\sigma 1}\right)}{\sigma 1}\right) \right\} + (1 - OSSj) \left\{ \ln\left(1 - \Phi(\psi 0i) + \ln\left(\frac{\phi\left(\frac{\varepsilon 0}{\sigma 0}\right)}{\sigma 0}\right) \right\} \right)$$

(6)

Where Φ (.) is cumulative normal distribution function and ϕ(.) is a normal density distribution function.

$$\psi ji = \frac{(Zi\pi + \frac{\rho j\varepsilon j}{\sigma j})}{\sqrt{1-\rho_j^2}}$$

$\rho_1 = \frac{\sigma_{1v}^2}{\sigma_1 \sigma_v}$ is correlation between ε_{i1} and vi , and similarly we can estimate ρ_0 . After calculating the parameters we can calculate conditional expectations (Lokshin And Sajaia, 2004):

$$E(yi1|\text{OSSj} = 1, xj) = \delta i1\ xj + \sigma_1 \rho_1 \frac{\phi(z_i \pi)}{\Phi(z_i \pi)} \quad (7)$$

$$E(yi1|\text{OSSj} = 0, xj) = \delta i1\ xj + \sigma_1 \rho_1 \frac{\phi(z_i \pi)}{1-\Phi(z_i \pi)} \quad (8)$$

$$E(yi0|\text{OSSj} = 1, xj) = \delta i0\ xj + \sigma_0 0 \frac{\phi(z_i \pi)}{\Phi(z_i \pi)} \quad (9)$$

$$E(yi0|\text{OSSj} = 0, xj) = \delta i0\ xj + \sigma_0 \rho_0 \frac{\phi(z_i \pi)}{1-\Phi(z_i \pi)} \quad (10)$$

CHAPTER 2

2. CHAPTER 2: THE FATE OF PATENTS: AN EXPLORATORY ANALYSIS OF PATENTS AS IPO SIGNALS OF REPUTATIONAL ADVANTAGE[32]

[32] This chapter is based on Working paper : Basir, N; Beyhaghi ,M; Mohammadi ,A; (2013), "The Fate Of Patents: An Exploratory Analysis Of Patents As IPO Signals Of Reputational Advantage".

2.1.INTRODUCTION

The primary focus of value for many corporations has been found in their intellectual property rights with inventors spending millions of dollars to protect their inventions. In the United States alone, inventors file over 540,000 patent applications a year with the U.S. Patent and Trademark Office (USPTO), a number that has grown steadily (USPTO Annual Report, 2012). Indeed, prior research has explored the proliferation of patents arguing different motives for patenting including blocking competitors (Cohen, Nelson, and Walsh, 2000), creating "fences" around commercialized products in order to prevent others from designing and selling substitute products (Cohen *et al.*, 2000; Shapiro, 2001), defending against patent infringement (Hall, Jaffe, and Trajtenberg, 2005; Hall and Ziedonis, 2001; Lemley, 2000, 2001), and as a way to increase a firm's reputation by showing it is innovative and an attractive investment (Blind, Edler, Frietsch and Schmoch, 2006; Hall and Ziedonis, 2001).

Once issued, a patent remains in force until 20 years after the patent application was originally filed[33]. To keep this 20-year term, the patent holder must pay maintenance fees at the four year, eight year, and twelve year mark. However, between 55 and 67 percent of issued U.S. patents lapse for failure to pay these fees before the end of their term (Lemley, 2000, 2001; Moore, 2005). In a survey of European patents, it was found that 38 percent of patents were never commercialized (Gambardella, Giuri, and Mariani, 2005). Other studies estimate that over half of all patented inventions are never commercially exploited (Lemley, 2000, 2001; Moore, 2005; Serrano, 2010; Sichelman, 2010). Although many of these undeveloped inventions can be considered commercially worthless (e.g., the anti-eating face-mask, beer bottle mini-umbrella, and weed-cutting golf club), the problem of underutilized patents

[33] Although patent laws across the world bear many similarities, there are some important differences especially when it comes to first to file versus first to invent, and maintenance fee amounts and schedules. For the purpose of this paper, the focus is on the U.S. patent system as the firms in the dataset are U.S based firms.

arguably applies to a large share of potentially valuable inventions. The researcher Adam Jaffe has stated in testimony before Congress “the patent system – intended to foster and protect innovation – is generating waste and uncertainty that hinder and threaten the innovative process”[34]. These patents are not only underutilized, but they may also prevent other firms from using them, thus potentially thwarting the evolution of innovation within an industry. This is especially alarming in industries, such as pharmaceuticals and biotechnology, where products are highly complex and innovations are incremental, cumulative, and dependent on downstream technology.

Although previous work provides insights on why firms patent, research has been limited in offering an explanation for the dramatic number of underutilized patents and the lack of commercialization. Our study builds on work that looks at patents as reputation signals (Hsu and Zeidonis, 2008; Long, 2002); however it analyzes the fate of those patents once they have been granted, an overlooked concept in the patenting literature. The focus of this paper is on the use of patents as signals of innovativeness. By acting as a signal, patents can inform observers about attributes of not just the patent, but the patentee itself and if patents are correlated with less readily observable firm characteristics, patents can serve as a signal of firm quality, more specifically, how innovative a firm is (Lemley, 2001). We argue that patents that are used for signaling intentions are more likely to be underutilized once their purpose has been exercised.

In this article, we focus on the initial public offering (IPO), to understand patenting practices prior to a major financing event, and the consequences of these practices on the patent itself. The IPO setting constitutes an excellent setting for this study as investors face great uncertainty and a high degree of asymmetric information when valuing IPO firms. They

[34] *U.S. House of Representative Oversight Hearing on the Patent System*, February 15, 2007

therefore rely on various signals of potential success to help overcome these risks (Haeussler, Harhoff, and Muller, 2009), patents being one of them.

Using data from the National Bureau of Economic Research (NBER), we build a multi-industry database of patents that expire due to lack of maintenance fee payments and test for a relationship between these patents and the IPO date of the patent owner. We find a significant and positive relationship between the likelihood of patents expiring due to lack of maintenance fee payments and the time to IPO. More specifically, we find that as a firm gets closer to its IPO date, the higher the patenting activity, and the more likely these patents are to be expired. We also observe that patents assigned to firms which are not associated with a venture capital (VC) are more likely to expire due to lack of maintenance fee payment. We posit that firms that use patents to signal reputational advantage are more likely to avoid paying maintenance fees, thus allowing the patent to expire. We also argue that signaling is more vital for firms which are not associated with another certifying third party, such as VCs.

Overall, this study contributes to the literature in several ways. First, it complements the economic literature on drivers of patenting behavior by exploring the consequences of patents sought for reputational and signaling purposes. In doing so, this study moves beyond the question of why firms patent, to examining longitudinally the fate of these patents. This study also brings to question the use of patents as indicators of innovative activity by investors, as firms may engage in patenting practices for alternative reasons. Thus, this study has practical implications but also implications for organization researchers that use patents as an indicator of innovative capabilities.

The structure of this article is as follows. In the following section we review the literature on reputation building, and signaling theory to develop our hypotheses. In the third section we introduce our dataset, methodology and analysis. Finally we conclude with a discussion of the findings, contributions, limitations and directions for future research.

2.2.THEORY AND HYPOTHESES

2.2.1. REPUTATION BUILDING THROUGH SIGNALS

The reputation of a firm is “a set of attributes ascribed to a firm, inferred from the firm’s past actions” (Weigelt and Camerer, 1988, pp. 443). A firm’s reputation therefore reflects stakeholder impressions of the firm’s disposition to behave in a certain manner (Clark and Montgomery, 1998), and incorporates information about how a firm compares to its competitors (Rao, 1994).

The importance of a company’s reputation as a source of competitive advantage is well established in the literature (e.g. Flanagan and O’Shaughnessy, 2005; Fombrun and Shanley, 1990; Hall, 1992) with reputation being argued to be one of the most important strategic resources associated with sustained competitive advantage (Amit and Schoemaker, 1993; Barnett, 1997; Barney, 1991; Flanagan and O’Shaughnessy, 2005). Although numerous studies have empirically linked firm reputation to its financial performance and social standing (Brown and Perry, 1994; Deephouse, 2000; Fombrun and Shanley, 1990; Roberts and Dowling, 2002), less research has focused on how a firm builds its reputation (Basdeo, Smith, Grimm, Rindova, and Derfus, 2006). Recent studies have emerged though which present frameworks on how reputations are constructed through market actions (Boot, Greenbaum and Thakor, 1993; Clark and Montgomery, 1998; Weigelt and Camerer, 1988), patterns of resource flows (Dierickx and Cool, 1989), market signals (Fombrun and Shanley, 1990; Heil and Robertson, 1991), and a combination of resource flows and strategic communications (Fombrun and Rindova, 1998; Reuber and Fischer, 2009; Rindova and Fombrun, 1999). These frameworks suggest that reputation formation can be broadly understood as a signaling process, in which the strategic choices of firms send signals to observers and observers use these signals to form impressions of these firms. Due to information asymmetries, stakeholders often use both actions and symbols to judge a firm's reputation and quality (Ferrier, 1997; Fombrun and Shanley, 1990; Spence, 1973). Thus, a firm's reputation is a "cognitive evaluation of the firm's quality that is socially constructed, but objectively held, by current and prospective constituents" (Reuben and Fischer, 2009).

Signaling theory describes the process used by decision makers in situations of information asymmetry (Spence, 1973). It posits that firms use visible signals to gain reputation and status among its stakeholders. Signaling theory has been applied in a number of settings including finance research, revealing that firms retain debt quality (Ross, 1977) or the issuance of dividends (Bhattacharya, 1979) to signal quality. In a number of IPO studies, based mostly in the accounting and finance literature, signaling theory has been used to show that managers send signals to investors to indicate firm quality and thus improve their IPO performance (e.g., Beatty, 1989 and Carter and Manaster, 1990). This line of research also demonstrates that the reputations of investment bankers (Carter, Dark, and Singh, 1998), auditors (Beatty, 1989), and venture capitalists (Megginson and Weiss, 1991) serve as signals in the IPO process. Within management, research framed in institutional theory and legitimacy has suggested that investor perceptions of board prestige signal organizational legitimacy (Certo, 2003; Higgins and Gulati, 2006). Higgins and Gulati (2006) argue that the top management team of a firm can serve as a powerful signal to investors that can in turn enable a firm to gain legitimacy, especially in young firms. Their findings show that investor decisions are affected by the employment affiliations and roles of top management team members and by partnerships the young firm has with prestigious lead underwriters.

Although the literature has investigated the signaling value of various third-party affiliations and management teams extensively, relatively little conceptual or empirical attention has been placed on the role of patents as quality signals for innovation (Hsu and Ziedonis, 2008). This study focuses on patents as signals and holds the assumption that patents meet Spence's (1974) criteria of a quality signal (Hsu and Ziedonis, 2008). According to Spence (1974), signals are only valuable to the extent that they are (i) observable and (ii) costly to imitate. In the context of patents, both conditions clearly apply. A patent is observable as it is documented in both the company documents, including in the prospectus documents prepared for IPO, and in the patent database of the country in which the patent is registered (for example, the USPTO in the U.S.). Finally, the purpose of a patent is to prevent others from imitating the innovation the patent describes, thus any attempts to imitate can be costly as they would be infringing on the patent. Furthermore, the direct monetary cost associated with the patenting process is estimated to be $25,000 and can exceed this number depending on factors such as the number of countries the patent is protected in, and its complexity (Lemley, 2000).

2.2.2. Patents as Signals in the IPO Context

Undertaking an IPO represents a significant event in the life of a firm as it moves from being a privately held company to a public trading one. In order for a firm to go public, managers prepare a standard set of documents for potential investors. To attract investors in the IPO process, managers and the firm's investment bank provide information regarding their firm and its potential, information that typically includes the firm's patent portfolio. As the IPO firm has been privately held, potential stakeholders are unaware of how the firm will perform. Therefore, the IPO firm must convince relevant audiences, particularly investors, that the firm has long-term potential[35]. To tap into a wide group of investors, firms must build a

[35] For example, a statement from the Facebook IPO states, "As of June 2012, we owned approximately 750 U.S. and foreign patents and patent applications. As of March 31, 2012, we had 774 issued patents and 546 filed patent applications in the United States and 96 corresponding patents and 194 filed patent applications in foreign countries relating to social networking, web technologies and infrastructure, and other technologies".

credible story that showcases their potential success. The patent portfolio of a firm helps build this story. This attempt to improve their reputation in front of potential investors is referred to as prestige-enhancing strategies that help improve investor valuation of the firm.

Investors face a tremendous amount of uncertainty associated with the quality of young firms undertaking an IPO due to information asymmetries. These companies typically have short histories and no market reputation, making measurement of their growth prospects, and hence valuation, difficult. IPO firms have not had the opportunity to establish consistent performance records in public markets; therefore they suffer from a liability of market newness (Certo, 2003; Stinchcombe, 1965). To compensate, young firms offer symbols of quality to convince external parties of the firm's potential. This logic echoes the work of Pfeffer and Salancik (1978) and March and Simon (1958), who suggested that an organization's most critical activity is gaining the support of social entities and stakeholders that can ensure the firm's survival. Stakeholders are more willing to exchange resources with firms when they have a more favorable impression of them (Hall, 1992; Rindova and Fombrun, 1999).

Furthermore, the assessment of a firm's quality is a perceptual, conditional and sometimes subjective attribute (Nadeau, 2010) under conditions of risk and uncertainty. The process of patenting generates signals that help to overcome these risks of newness faced by new ventures (Haeussler, Harhoff, and Muller, 2009). Although there has been mixed findings on how effective patents are for securing returns to innovation (Cohen *et al.*, 2000), an area where patents are viewed as highly important is in securing financing to start new ventures (Hall and Ziedonis, 2001). Studies have shown a positive relationship between patenting and the total VC invested by technology firms (Baum and Silverman, 2004; Mann and Sager, 2007), firm valuation and the likelihood to attract a prominent venture capitalist investor (Hsu and Ziedonis, 2013) and the ability to attract financing sooner (Haeussler, et al., 2009). In a study of 370 VC-backed semiconductor start-ups, Hsu and Ziedonis (2008) found that patents served as quality signals influencing investor estimates of start-up firm value, where a doubling in patent application stock was associated with a 28 percent boost in funding-round valuations beyond what would otherwise be expected. The authors also found that a larger patent application stock increased the likelihood of sourcing initial capital from a prominent VC. Similarly, Baum and Silverman (2004) found a positive association between USPTO patent applications and pre-IPO VC financing for biotechnology firms. Thus, we posit that as firms near critical financing events, they are likely to increase activities that signal a reputational advantage. Patents offer a signal to potential investors looking for indicators of innovation and value under conditions of uncertainty. Therefore as the IPO date draws near, firms increase their patenting activity to attract potential investors. In sum, it would be expected that:

Hypothesis 1: Patenting activities increase as a firm gets closer to its IPO date.

However, if we take the idea that patents act as reputational signals, then they may not necessarily reflect true innovative capabilities. Firms that apply for patents prior to the IPO date for signaling purposes may not have plans to commercialize or appropriate any rents from this patent (for example via licensing agreements). These patents may not necessarily even meet the requirements necessary for a patent to be granted. The purpose of these patents may be solely to attract investors. This argument rests on the idea that these patents are used primarily for signaling purposes. This is different than the argument that their purpose to protect innovations with a latent function being their signaling capability for investors. Therefore, it would be expected that those patents that are used solely for the purpose of signaling may be of lesser quality than those patents used for rent appropriation. And thus,

Hypothesis 2: Patents filed closer to the IPO exit date are more likely to be underutilized.

The literature investigating the signaling value of third-party affiliations demonstrates that the reputations of investment bankers (Carter, Dark, and Singh, 1998), auditors (Beatty, 1989), and venture capitalists (Megginson and Weiss, 1991) serve as signals in the IPO process. Acquiring venture capital investment is one of the most important milestones for private firms, as venture capitals not only provide financial resources, but also create value for the firm (Ueda, 2004; Gompers and Lerner, 1999; Sapiena, Manigart and Vermiel, 1996; Gorman and Sahlman, 1989). Private firms look for high quality investors (Bygrave and Timmons, 1992; Hsu, 2004; Sorenson, 2007) who can provide better value-added or lease their reputation to the firm as a signal of quality to the outside world (Hsu, 2004; Hsu and Ziedonis, 2013). Megginson and Weiss (1991) show the certifying impact of VCs in IPO markets by comparing two match samples of VC-backed and non VC-backed firms that have gone public. They show that the presence of a VC reduces the total cost of IPO and under-pricing.

Affiliation with a VC is a strong signal of quality to outside firms, therefore using patenting activity as a reputation signal is less relevant for VC-backed firms and contrarily it is more relevant for non VC-backed firms which lack alternative ways for signaling quality to outside investors. Overall, these factors suggest our third hypothesis:

Hypothesis 3: Patents filed closer to the IPO exit date are more likely to be underutilized, when issuers are not with a venture capital (that is when there is no certifying third party).

2.3.METHODS

2.3.1. DATA AND SAMPLE

We obtain our primary sample of patents from the National Bureau of Economic Research's (NBER) patent database (Hall, Jaffe, and Trajtenberg; 2001), which contains detailed information on patent applications and grants, the identifications of patent inventors and assignees, the technology class of patents, numbers of citations made and received by each patent and different measures of originality and generality of patents. This data set consists of all U.S. patents granted during the period 1963-1999 (three million patents) and all patent citations made during 1975-1999 (about 16 million citations). The primary sources of data for NBER are reports and announcements by the USPTO, an agency at the Department of Commerce.

The maximum term for all U.S. patents is 20 years from the date of the application. Based on the *United States Patent and Trademark Office Fee Schedule*, a patentee must pay a maintenance fee before the four year anniversary of the patent being granted, and subsequently after the eight year mark, and twelve year mark. The USPTO also allows patent reinstatements if the failure to pay was due to an unavoidable or unintentional delay. To show unintentional delay, the patentee has to file a reinstatement petition within twenty-four months after the six month grace period. Therefore, the sample we employ includes 282,426 patents granted in 1997, 1996 and 1995. Choosing these years enabled us to capture whether the patent was renewed at the four year points (2001, 2000, and 1999), eight year points (2005, 2004, and 2003) or twelve year points (2009, 2008, and 2007) and an additional two year window within which patents can be reinstated. We limit our sample to patents filed during and after 1995 following the introduction of the Word Trading Organization's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs Agreement) in 1994. Under this agreement the term of all patents in the United States has to be harmonized at 20 years.

In order to verify the maintenance status of a patent we rely on the Thompson Innovation database which reports any official update on the status of the patent (INPADOC legal status)[36]. The INPADOC legal status data is collected by national offices that report post-issuance activities (e.g. for US patents USPTO). By looking at the INPADOC legal status we can evaluate whether maintenance fees were paid as well as the number of times they were paid. If the maintenance fees were paid three times, it means the patent completed its 20 years life cycle. Similarly two payments indicate that the patent has expired after 12 years, and one payment indicates expiry after 8 years. Finally, if a fee was never paid, we can conclude that the patent expired after 4 years.

Removing all-non-US companies and those patents belonging to government institutions narrowed the 282,426 cases from NBER down further to a sample of 201,627 patents. Additionally, the Thompson Innovation data does not report legal status for 8 percent of patents; therefore we limit our sample only to patents with reported legal status. This procedure leaves us with 186,600 patents. The third data source used in this study is the Thomson Financials SDC Platinum United States New Issues dataset (hereafter SDC), from which we obtain data on IPOs by U.S. corporations. The SDC database provides detailed information on all new issues from the beginning of 1962. We match our patent data to SDC to track the IPO dates and proceeds for patent assignees. Out of 186,600 patents (representing 21,361 assignees) about 55 percent have CUSIP identifiers that allow for matching with firm level financial data. The rest of the original sample belongs to firms that stay private, or firms that have gone public but for which Hall et al. (2001) could not find a concordance with public firm filings.

A key characteristic that represents a firm's maturity and experience is the firm's age, calculated as years from the firm's founding date. We use this variable to control for the age factor when we derive conclusions on both the timing of IPO decisions and the amount of

[36] http://www.thomsoninnovation.com/tip-innovation/support/help/patent_fields.htm#inpadoc_legal_status

patenting activities. To calculate the age of a firm at the time of patent application and IPO, a founding date is needed. The SDC provides founding dates for some issuers (about one third) as an additional feature[37]. As a result, the final sample includes 30,891 patents from 385 assignees (hereafter full sample).

In order to examine Hypothesis 2 we require distinguishing between firms that receive VC funding and those firms that do not. To do this, we use data on VC funding from VentureXpert (from SDC Platinum). The VC industry was very small until the late 70s (Gompers and Lerner, 1995), hence, in order to prevent selection issues, when we test hypothesis 2, we limit the sample further to firms founded after 1970[38]. After incorporating this data the sample falls to 6,255 patents belonging to 89 firms (hereafter the limited sample)

2.3.2. INDEPENDENT AND DEPENDENT VARIABLES

Our hypotheses examine the relationship between a firm's patenting activity and the timing of IPO. More specifically, we are interested in testing how proximity to IPO date affects the quantity and the quality of a firm's patenting activity. Therefore, the key independent variable in our analyses is the time difference between a patent's application year and IPO date and a *Non-VC* variable to control for VC investment. The dependent variables encompass various measures of the quality as well as the quantity of patenting activity around IPO dates. The dependent variables are discussed in detail here. We also control for other variables that may affect IPO decisions and the quantity or the quality of patenting activities. A detailed description of all variables (dependent, explanatory and control variables) can be found in the <u>Appendix</u> .

[37] To further control for reporting errors, we exclude observations with founding dates greater than IPO dates (78 observations).

[38] In order to check that our results are not driven by the choice of starting year we repeated the analysis separately for firms founded after 1975 and 1965. The results are qualitatively similar.

We use five dependent variables in this study. The first variable, *Number of Patents Applied*, refers to the number of patents a firm in our sample has applied for in each year. We use a dichotomous outcome of a patent being eventually expired or not as the second dependent variable, *Expired*. This variable receives a value of 1 if a patent expires before 20 years[39] after its grant date; and receives a value of 0 otherwise. In a logistic regression setup, we test whether the proximity of IPO date increases the likelihood that a patent applied for will expire in the future, after controlling for different firm and patent characteristics. The third variable, *Expiration Category,* represents a categorical outcome that a patent experiences with respect to expiration time. The *Expiration Category* can receive a value (an integer) between and including 1 and 4, where a value of 1 represents a patent expiration at 4 years; a value of 2, represents expiration at 8 years; and a value of 3, representing expiration at 12 years. A value of 4 represents no expiration prior to the 20 year term of a patent life. The patenting procedure in the U.S. market provides a setup to test Hypothesis 2 in a finer way. The holder of a patent is required to pay a renewal fee every four years in order to prevent early expiration. Thus if Hypothesis 2 holds, we should expect that a patent applied for near a firm's IPO date is more likely to expire sooner than later, that is, it belongs to a lower category than a higher category. For example a patent that is issued right before the IPO date is more likely to belong to category 1 (i.e. expires after 4 years) rather than to category 2 (expires after 8 years). We use *Expiration Category* in an ordered logistic framework due to the ordered nature of these categories.

We use a continuous variable, *Patent Age*, as another measure of a patent's utilization. *Patent Age* is defined as the difference between the year a patent is expired and the grant date of the patent. The previous three measures were discrete variables that are used in logistic set-ups. Using *Patent Age* as a continuous variable facilitates examining the robustness of the

[39] We repeated the models for patent which have expired at 8 years.

results in our discrete-variable analyses. Similar results found under both frameworks would suggest that the results are robust and independent of model specifications. Finally, we use a dichotomous variable, *Non-VC,* to test Hypothesis 3. We also use this variable to test for an interaction relationship with the *Expired* variable. Patents belonging to firms without VC funding at the time of application receive a value of 1 for this variable and 0 otherwise.

2.3.3. CONTROL VARIABLES

We control for confounding factors that can have impact on underutilization of patents. We do so by considering two types of variables, firm characteristics and patent characteristics. Regarding firm characteristics, we control for the age of the firm at the time of the patent's application, size of IPO (million Dollar value) and the number of patents granted to the firm. We also control for patent characteristics, such as backward citation, number of claims, number of inventors, number of assignees, number of patents classes assigned to the patent and grant time calculated as time difference between applications and grant year, previously mentioned in prior literature (e.g. Trajtenberg, et al., 1997). Additionally, in order to capture differences in industries and across years we control for industry and application year fixed effects. We do so by adding 6 dummy variable referring to the 6 ISIC based industries: Chemicals, Computers and Communication, Drug and Medical , Electrical and Electronics, Mechanical and Others(apparel, furniture, etc.). Also we include dummy variables for application year of patent[40].

2.4.ANALYSIS

We test our hypotheses using four analytic approaches to examine the effect of being in a pre-IPO on patenting activity (Hypothesis 1) as well as the likelihood a patent will be underutilized (Hypothesis 2), and the impact the lack of affiliation with a VC has on the

[40] For robustness check we also controlled for States (50 States in US) where patent were filed. Additionally, in addition to control for variation in patent classes, we controlled for number of patents that expired within same patent class (one digit patent class) of focal patent and were granted at the same year as focal patent. The results are qualitatively similar. The results are not reported and are available upon request.

likelihood of a patent being underutilized (Hypothesis 3). The first approach is a uni-variate analysis in which the relationship between patenting activity and the proximity of the IPO date is demonstrated. In this approach we show how patenting activity of our sample firms changes between the five years before the IPO date and the five years post-IPO date. If Hypothesis 1 holds we expect patenting activity to increase before the IPO date. Hypothesis 2 and 3 are examined using multi-variate approaches in 3 models. The following regression models belong to each approach respectively. In all models we use two sub models. In sub-model 1, the pre-status variable is patent application 5 years prior to IPO while in the second sub-model pre-status variable is patent application 3 years prior to IPO. All sub-models have an additional interaction term between pre-IPO Status and Non-VC variables that allow us to test Hypothesis 3.

(1) Expired = A + B (Pre-IPO Status) + C (Non-VC)+ D (Firm Characteristics) + E (Patent Characteristics)

(2) Expiration Category = A2 + A3 +A4 + B (Pre-IPO Status) + C (Non-VC) + D (Firm Characteristics) + E (Patent Characteristics)

(3) Patent Age = B (Pre-IPO Status) + C (Non-VC)+ D (Firm Characteristics) + E (Patent Characteristics)

In each model we examine whether proximity to the IPO date has an impact on the utilization of patents applied for, controlling for various firm and patent characteristics. The proximity to the IPO date is measured by the variable *Pre-IPO Status* which is a binary variable that is assigned a value of 1 if the patent is applied for within five years before IPO date, and 0 otherwise. Additionally we use a 3 year period as a robustness check. The utilization of a patent is measured by the likelihood of its expiration [Model (1)], the likelihood of an early expiration [Model (2)], and the age of the patent [Model (3)].

Model (1) is run under a dichotomous outcome setting (logistic regression). Model (2) is examined under a categorical outcome in which the dependent variable can have four values representing patent expirations at 4, 8, 12, or 20 years. We use an *Ordered Logit* framework to test this model. The dependent variable in Model (3) is continuous and we use an ordinary least square regression[41] to examine this model. As a robustness check we also control for industry effects. These three models have different methodological structures, enabling us to check the validity and the robustness of our conclusions. In order to solve problems that may arise due to several observations belonging to an assignee, we cluster errors around assignee in all models.

2.4.1. RESULTS

Table 2-1 provides summary statistics for the number and percentage of underutilized patents across all industries in the full sample of 30,891 patents. The results show that the rates of expiration vary across technology fields. Of the total number of patents in our sample, 71.03 percent eventually expire due to failure to pay maintenance fees. The average number of patents granted in an industry is 5.148, with the *Computer and Communication* category having the largest number of grants, and *Drug and Medical* category holding the least number of patents. All industries have more patents expiring than those not expiring. It can be seen that the *Mechanical* category holds the greatest number of patents that fail to be renewed. Most patents expire at the 4 year mark.

[Table 2-1 about here]

[41] We also used a Negative Binomial model and results are qualitatively similar.

The percentages of patents expired after issuance is provided in Table 2-2. This table shows that only about 30 percent of patents issued during 1995 to 1997 are not expired. Moreover, Table 2-3 provides summary statistics of patent level variables. The average and median expiry years for a patent in our sample are 10.81 and 8 years respectively. All patents are given a value of 4, 8, or 12, corresponding to the year the patent expired due to failure of paying maintenance fees, or a value of 20 meaning the patent did not expire with the assumption that if the 12 year maintenance fee is paid, then the patent will complete its life and lapse at 20 years. The table also reports statistics on the years a patent is applied for (the grant year is 1997, 1996 and 1995 for the patents in the sample) and the age of patent assignee at the time of application. The earliest and the median year a patent was applied for are respectively 1967 and 1994. The average and median time between patent application year and grant year are 1.93 and 2 years respectively, which is consistent with prior studies (Hall et al., 2001). Patents granted in 1997, 1996 and 1995 follow similar trends in expiration, with approximately 70 percent of patents expiring.

[Table 2-2 about here]

[Table 2-3 about here]

Table 2-4 provides descriptive statistics at the firm level. This table shows that the sample is skewed to older firms as indicated by the median founding year being 1942. The average age at which a firm files for an IPO is 48.16 years. Table 2-4 also shows that the average and median logarithm of the size of IPO proceeds equate to 4.89 and 4.71 respectively (equivalent to 132.93 and 111.05 million dollars). We also find that firms can vary in the number of patents they have been granted per year, from only 1 patent to the maximum of 1405 patents, with 6 being the median number of patents obtained and 34.10 the mean. Although we look at the number of patent applications per year for patents with grant years of

1997, 1996 and 1995, on average each firm applied for 21.42 patents per year with a median of 4.

[Table 2-4 about here]

A schematic relationship between patenting activity and the proximity of the IPO date is demonstrated in Figure 2-1. This figure illustrates the trend in the average number of patents applied for by a firm within 5 years before and after IPO date. For this analysis we limit the firms in our sample to those firms which we have data that falls within five years pre and post their IPO date. We choose 5 years to allow for observations of patenting activity prior to IPO, assuming a firm will practice reputation-enhancing activities within the 5 years leading to IPO. The 5 years post IPO allow for enough lag time to observe any change in patenting activity once the firm has filed an IPO. Many firms in our sample have gone public before they enter into our sample, or their IPO date is within or after the 5 years prior to the last year of our sample. This leads to a sample of 2,641 patents belonging to firms which fall within five years pre and post IPO date. This sample is used to test Hypothesis 1. Figure 2-1 shows an increase in patenting activity before the IPO date and the subsequent decline after IPO. Peak activity is at minus 2 years, which is particularly interesting given that the average time elapsed between the years a patent is applied for and the time it is granted is 2.09 years (see Table 2-3). A simple t-test verifies the difference on mean number of patents 5 years prior to IPO (85.23) and 5 years after IPO (76.10). The difference is statistically significant at a 1 percent level. These findings suggest that firms may be intentionally timing their applications with intended IPO dates bearing in mind that the average patent takes about two years after application date to be granted. These findings support Hypothesis 1.

[Figure 2-1 about here]

Table 2-5 reports correlations between dependent, independent and control variables in model (1). These variables are used in the multi-variate analyses to follow.

[Table 2-5 about here]

To examine Hypothesis 2, we first study the distribution of expired patents with respect to the proximity of patents' issue dates and their assignees' IPO dates. Table 2-6 shows that while 84.26 percent of patents filed within 5 years prior to IPO expire, this number is much less (68.68 percent) for those patents that do not. A proportion test and Pearson's chi square test verifies that two groups are distributed significantly differently (p-value of 0.000). Tables 2-7, 2-8 and 2-9 present the results of running Models (1), (2) and (3) respectively. Each table provides two groups of results (or two sub-models). Results for each sub-model differ from each other in the choice of the main independent variable, which is a dummy variable indicating when the patent application occurred from the firm's IPO date. In sub-sample 1 this dummy variable is assigned a value of 1 if the application has happened within 5 years prior to IPO date and in Sub-model 2 this dummy variable is assigned a value of 1 if the application has happened within 3 years prior to IPO date. Our results are robust to different timeframes we consider for this dummy variable.

[Table 2-6 about here]

Table 2-7 demonstrates that firms that are about to IPO are more likely to apply for a patent that will expire before 20 years after the application year. The results for each sub-sample are presented in three columns differing in the choice of control variables used to test Hypotheses 2 and 3. The first two columns (columns 1 and 2 in sub-sample 1 and 4 and 5 in sub-sample 2) provide results on hypothesis 2 and the last columns (column 3 in sub-sample 1 and column 6 in sub-sample 2) provide results on hypothesis 3. Columns 1 and 4 report the result for the full sample while column 2 and 5 repeat the analysis on the limited sample. The coefficient is significantly larger for the limited sample (which includes firms founded after 1970). This provides further evidence on the signaling nature of patents. Since younger firms have higher information asymmetries with market participants, the marginal effect of a signal is larger for them in comparison with more mature and well established firms. Moreover, the coefficients for the same variable in columns 2 and 5, where a non-vc dummy is included, are 4.02 and 3.82, both significant at a 1 percent level. This implies a 37 percent and a 36 percent increase in the probability of expiration when a patent is filed closer to issuer's IPO date. These results provide support for Hypothesis 2.

[Table 2-7 about here]

Columns 3 and 6 in Table 2-7 report the results for Hypothesis 3. Consistent with Hypothesis 3, we find a positive and significant coefficient on the interaction terms, *Non-VC* and *pre-IPO status*. This verifies that the magnitude of the effect of being near the IPO time on likelihood of expiration is greater for firms that are not associated with a VC. As VCs can play a significant role as certifying agents in the IPO market (Meggison and Weise, 1995), these results suggest that firms which are not associated with a VC are more likely to use patents as signals of quality to outside investors near IPO time. The coefficients in columns 3 and 6 (sub-models 1 and 2) respectively are 3.81 and 3.62 and are both statistically significant at 5 percent. These coefficients represent the change in the log odds of patent expiry as a non VC-backed issuer approaches the IPO date. The result can be interpreted as a 34 percent and a 33 percent higher probability of patent expiration if the issuer is a non-VC backed firm.

Table 2-7 also shows other interesting results. For instance, patents with more International Patent classes (IPCs) are more likely to expire. This result is statistically significant. The number of *claims* made adversely affects the likelihood of being expired. The number of claims is indicative of the scope or width of an invention (Hall et al., 2001). Patents with a higher number of claims are generally more expensive to apply for, and therefore can indirectly measure the importance of the patent for the assignee. Finally the models control for year and industry fixed effect and error terms are clustered around assignees to avoid any bias that might be created from differences in patenting activities across different industries and firms that may be applying for more than one patent during the sample period.

[Table 2-8 about here]

Table 2-8 also provides additional insight into the patenting activity relative to Table 2-7. The nature of our data facilitates using a finer technique, known as the proportional odds technique or an ordered logistic model. The dependent variable is a categorical variable. It is assigned a value of 4 if a patent never expires. It is equal to a value of 3, 2 and 1 respectively if the patent expires at 12, 8 or 4 years. The interpretation of coefficients in this technique is similar to the interpretation of an ordinary logistic regression – except there are three transitions estimated here versus one – as there would be with a dichotomous dependent variable. A patent applicant being close to the time of IPO decreases the likelihood of the patent expiration at a higher level. In other words it is more likely for a patent to expire in 4 years versus in 8 years, and similarly in 8 years versus 12 years and finally in 12 years versus 20 years. The intercepts can then be used to calculate what the predicted probability is for a patent, with a given set of firm-patent characteristics, being in a particular expiration category.

Table 2-8 presents the results of Model (2) in an ordered logistic regression framework where results and coefficients support the results found in Table 2-6. In column 1 the coefficient is negative, as expected, and not statistically significant (p-value 0.11). However, the addition of the interaction term, makes it statistically significant at 1 percent level, thus strongly supporting Hypothesis 3. The results suggest that being close to IPO matters specifically when the firm is not VC-affiliated. In other words, firms are more likely to use patents as reputation signals when a third-party certification is lacking. The control variable, *assignee count*, has an insignificant coefficient in Table 2-7; however in Table 2-8 the coefficient is significant and adversely related to the dependent variable in this model.

[Table 2-9 about here]

Finally, Table 2-9 presents the results of an Ordinary Least Square regression used to test Model (3). Supporting our previous results, this model demonstrates that firms apply for patents that expire faster when they are close to their IPO date. Table 2-9 illustrates results for Model (3) under 2 different sub-models. The results overall support our previous findings.

2.5.DISCUSSION AND CONCLUSION

Overall, the results of this study show support for the argument that when firms patent for the purpose of building a reputation, there is a greater likelihood for these patents to eventually be rendered underutilized. We find a significant and positive relationship between the likelihood of patents expiring due to lack of maintenance fee payments and the time to IPO. We also find that patents associated with firms which are not venture capital backed, are more likely to expire.

Patents continue to act as indicators of firm innovation activity (Heeley, Matusik, and Jain, 2007). Patent data offers a unique combination of detail and coverage which make them particularly well suited for innovation related studies (Lanjouw, Pakes and Putnam, 1998). Patent data is available for all firms and individuals for a long period of time, and whereas R&D expenditure data have been the most commonly used alternative, they are more related to inputs into the innovative process than to outputs (Lanjouw et al., 1998). Research typically relied exclusively on simple patent counts as indicators of some sort of innovative output (see Griliches, 1990 for a review). However, it is now recognized that innovations vary immensely in their importance, impact, and economic value (Hall et al., 2001, 2005) and thus the patent count method often runs into difficulties. Schankerman and Pakes (1986) challenged previous studies that showing that the patent/R&D ratio declined rapidly over time in most Western countries, indicating a period of ‘technological exhaustion’ (Lanjouw et al., 1998). They compared aggregate patent count indices to their estimated patent value inidces for each of the UK, France and Germany for the period of 1955 to 1975 and concluded that ‘…one cannot draw inferences on changes in the value of cohorts of patents during this period from changes in the quantity of patents, for there have been large (and laregely offsetting) changes in the ‘quality’ (or mean values) of patents’. Other studies followed showing that variations in patents exist. For example, decreases in patent counts were found to be partially offset by increases in the average value of the patent (Pakes and Simpson, 1989; Schankerman, 1998) and patents from different ISIC industry categories have different value distributions as well (Pakes and Simpson, 1989). Lanjouw, Pakes and Putnam (413:1998) state ‘indeed one of the longest lasting debates in the history of economic measurement has been whether the noise and the biases in patent count measures can be made small enough to make patent counts useful measures of innovative output in economic studies’. This article reiterates the problems faced with the use of patent counts and the call for the use of both renewal and application data to develop a weighted patent count measure (Lanjouw et al., 1998; Lanjouw, 1998; Pakes, 1986; Pakes and Schankerman, 1984).

This study contributes to the patent literature in a number of ways. First, this study expands the literature on why firms patent by underscoring the role that reputation plays in whether a firm is likely to use patents to signal value to potential investors. In doing so, this study challenges the notion that patents reflect a firms actual innovative potential and suggests that often patents are never commercialized. As Jaffe notes, this finding suggests that patenting has evolved from a system to protect innovation to a system of illusionary signaling that may often not be indicative of true innovative capacity. The information contained in a patent provides little information about the ability of the firm to extract value from the invention unless the reader of the patent is 'skilled in the art' (Heeley, Matusik, and Jain, 2007). Although investors look for the quality *and* quantity of patents in a potential firm, the reality is that often the content of the patent does not provide usable information to the majority of members of the investment community (Heeley et al., 2007).

A second contribution of this study stems from its focus on the life cycle of patents. Particularly, as there is very little work on underutilized patents (see Moore, 2005 for an exception), this study offers a unique opportunity to track the creation and evolution of patents that fail to commercialize.

Third, whereas previous work, for the most part, takes a cross-sectional approach by examining the economic motives for whether a firm chooses to patent or not, this study contributes to the literature and extends this stream of work by adopting a longitudinal perspective that explores the fate of patents once they have been granted.

Our study has some limitations that may also present fruitful avenues for future research. One limitation of this study is that it focuses on signaling at the IPO period. Although the IPO context is a very relevant event for this study, there are other events in the life of a firm that could be interesting to investigate and perhaps validate the findings of this study. It is possible that once firms IPO R&D direction may change and thus patents that were once of interest to the firm are no longer. Additional research that investigates other reputation enhancing events could provide additional insight as to whether underutilization is a reflection of the intended purpose of the patent as a signal or a change in R&D focus. Second, of great interest are those patents that expire at 12 years. Why would a firm let a patent go after 12 years of maintenance? It is one thing to hold a patent for 4 years, and pay one set of fees and decide that the cost to maintain it are greater than its potential worth, but as the results indicate, there are many patents that only expire at the 12 year mark. Third, this study looked at only one of the many strategic uses for patents. Others that have been cited in the literature and in this article include the use of patents to prevent litigation, to build fences, and blocking competitors. Similar studies to this one could be designed to investigate the fate of those patents used for these strategic reasons. Finally, this research used secondary data. An important direction for future studies would be to complement a large-scale quantitative study with qualitative research analyzing decision making at the patent level. A qualitative study that looks at both the decision makers in a firm and their patenting motives as well as the investors valuating these companies would likely provide rich process data that would offer additional depth and breadth. A complementary qualitative study would also help address the limitations previously discussed.

Beyond research implications, this study also offers some practical implications from a management, investor, and policy perspective. Managers need to balance the need to show investors they are innovative and have a strong patent portfolio that protects their innovations, with the need to not be sitting on innovations that may be of value to a company through commercialization means or licensing means. From an investor's perspective, investors need to realize that the quantity of patents may not be a good indicator of how innovative a company is. Although patents have a history of being used as proxies for innovation, we see the numbers of patents increasing exponentially, but commercialized innovations on a decline (Gold, 2008). There is a need to revisit the innovation construct in relation to patents.

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2.7.TABLES:

Table 2-1- Summary of expired patents by industry

	# Patents	Expired (%)	Exp at 4 yrs (%)	Exp at 8 yrs (%)	Exp at 12 yrs (%)	Did not expire (%)
Chem[a]	3,700	2,704 (73.08)	1,225 (33.11)	856 (23.14)	623 (16.84)	996 (26.92)
C&C[b]	9,671	6,432 (66.51)	3,366 (34.81)	1,354 (14.00)	1,712 (17.70)	3,239 (33.49)
D&M[c]	1,400	807 (57.64)	382 (27.29)	271 (19.36)	154 (11.00)	593 (42.36)
E&E[d]	8,303	5,971 (71.91)	2,893 (34.84)	1,617 (19.47)	1,461 (17.60)	2,332 (28.09)
Mech[e]	5,036	4,037 (80.16)	1,749 (34.73)	1,326 (26.33)	962 (19.10)	999 (19.84)
Other[f]	2,781	1,991 (71.59)	931 (33.48)	584 (21.00)	476 (17.12)	790 (28.41)
Total	30,891	21,942 (71.03)	10,546 (34.14)	6,008 (19.45)	5,388 (17.44)	8,949 (28.97

[a] Chemical, [b] Computers and Communication, [c] Drugs and Medical, [d] Electrical and Electronics, [e] Mechanical, [f] Other (apparel, furniture, etc).

Table 2-2- Summary of expired patents by grant year

	Grant Year			
	1995	1996	1997	Total
Not expired (%)	2,639 (26.04)	3,115 (29.12)	3,195 (31.75)	8,949
Expired (%)	7,494 (73.96)	7,581 (70.88)	6,867 (68.25)	21,942
Total	10,133	10,696	10,062	30,891

Table 2-3- Descriptive statistics of patent level variables

Variable	Mean	Std Dev	Min	25th Pctl	Median	75th Pctl	Max
Patent Age (Year Expired)	10.81	6.48	4	4	8	20	20
Patent Application Year	1994	1.26	1967	1993	1994	1995	1997
Time Elapsed from Patent Application to Grant	1.93	1.03	0	0	2	2	29
Number of Claims	16.03	11.97	1	8	14	20	200
Citations Made	12.15	11.73	0	5	9	15	182
Number of Inventors	2.32	1.43	1	1	2	16	20
Number of Assignees	1.00	0.10	1	1	1	4	4
Number of IPC	1.78	1.00	1	1	1	2	8
Assignee Age	54.31	27.47	0	26	64	78	95

N = 30,891

Table 2-4- Descriptive statistics of firm level variables

Variable	Mean	Std Dev	Min	25th Pctl	Median	75th Pctl	Max
Year Patent Assignee Founded	1942.68	27.66	1901	1919	1942	1970	1995
IPO Year	1990.84	9.79	1970	1983	1990	1997	2012
Assignee's Age at IPO Year	48.16	30.64	0	14	55.5	75	109
IPO Size $m (log)	4.89	1.35	-0.005	3.99	4.71	6.23	7.66
Number of Patents Granted per year	34.09	103.92	1	2	6	605	1405
Number of Patents application per year (granted on 1997, 1996, 1995)	21.42	73.11	1	2	4	560	1435

N = 370

Table 2-5- Correlation between main dependent (expired=1 for underutilized patents), independent and control variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)	(10)	(11)	(12)
Expired	1											
Application was in [-5,0] of IPO	0.2518	1										
Non-VC	0.1602	0.5052	1									
Time Elapsed from Patent Application to Grant	-0.0248	0.0318	-0.0375	1								
IPO Size	0.0156	0.0355	0.0007	0.032	1							
Age of firm at the Time of Application	-0.185	-0.3905	-0.5161	-0.1267	0.3685	1						
Number of Inventors	-0.0328	0.0357	-0.0453	0.0572	0.2242	0.0976	1					
Number of IPC	0.0514	-0.0332	-0.0326	0.0766	0.2733	0.0618	0.112	1				
Assignee Count	0.0131	-0.0079	-0.0155	0.0484	-0.0258	-0.0143	0.0275	0.0232	1			
Citations Made	0.0292	0.0227	0.0184	0.0121	-0.0011	-0.0369	0.1152	0.0301	0.0066	1		
Number of Claims	-0.147	-0.0892	-0.0234	0.0538	-0.1137	-0.0045	0.0261	-0.0123	0.0268	0.0489	1	
Number of Patents	-0.0768	0.054	-0.1135	-0.1372	0.2001	0.2875	0.0104	-0.065	0.0126	-0.0661	0.0247	1

Table 2-6- Distribution of expired patent and time to IPO

	Application was in [-5,0] of IPO		
expired	0	1	Total
0	8216 (31.32)	733 (15.74)	8,949
1	18019 (68.68)	3923 (84.26)	21,942
Total	26,235	4,656	30,891

N=30,891

Table 2-7- Patent-level analysis: Relationship between time to IPO and likelihood of patent expiry

	Sub-Model 1			Sub-Model 2		
	(1)	(2)	(3)	(4)	(5)	(6)
Application was in [-5,0] of IPO	**0.8270***	**4.0228*****	**1.2793*****			
	(0.4552)	**(1.1767)**	**(0.4531)**			
Application was in [-3,0] of IPO				**0.9393****	**3.8178*****	**1.2596*****
				(0.4572)	**(1.1093)**	**(0.4600)**
Non-VC		-0.7146	-0.7790		-0.5938	-0.6533
		(0.7912)	(0.7730)		(0.7952)	(0.7783)
IPO_5yr*NON-VC			**3.8170****			
			(1.5466)			
IPO_3yr*NON-VC						**3.6185**
						(1.5306)**
Time Elapsed from Patent Application to Grant	0.0251	-0.0417	-0.0307	0.0220	-0.0304	-0.0186
	(0.0410)	(0.0914)	(0.0936)	(0.0398)	(0.0977)	(0.1002)
IPO Size		0.0004	0.0004		0.0005	0.0005
		(0.0007)	(0.0007)		(0.0007)	(0.0007)
Age of firm at the Time of Application	0.0100	-0.0468	-0.0436	**0.0105***	-0.0515	-0.0484
	(0.0062)	(0.0658)	(0.0655)	**(0.0063)**	(0.0668)	(0.0664)
Number of Inventors	-0.0045	-0.0358	-0.0355	-0.0060	-0.0352	-0.0348
	(0.0239)	(0.0341)	(0.0338)	(0.0237)	(0.0343)	(0.0340)
Number of IPC	0.0453	**0.2151*****	**0.2181*****	0.0401	**0.2087*****	0.2114***
	(0.0387)	(0.0807)	(0.0809)	(0.0389)	(0.0809)	(0.0809)
Assignee Count	**0.6318*****	0.9260	0.9281	**0.6246*****	0.9100	0.9110
	(0.2428)	(0.6378)	(0.6404)	**(0.2372)**	(0.6342)	(0.6366)
Citations Made	-0.0004	0.0061	0.0063	-0.0004	0.0058	0.0061
	(0.0038)	(0.0072)	(0.0073)	(0.0037)	(0.0072)	(0.0073)
Number of Claims	**-0.0079****	**-0.0187*****	**-0.0186*****	**-0.0082****	**-0.0193*****	**-0.0193*****
	(0.0036)	(0.0059)	(0.0059)	**(0.0036)**	(0.0059)	(0.0060)
Number of Patents	**0.0010****	-0.0033	-0.0036	**0.0011****	-0.0032	-0.0035
	(0.0005)	(0.0045)	(0.0044)	**(0.0005)**	(0.0045)	(0.0044)
Grant year dummies	YES	YES	YES	YES	YES	YES
Industry Fixed effect	YES	YES	YES	YES	YES	YES
Constant	-0.5829	1.6360	1.6054	-0.5728	1.6447	1.6111
	(0.5025)	(1.6143)	(1.6156)	(0.4996)	(1.6187)	(1.6190)
N	30,891	6,255	6,255	30,891	6,255	6,255

Table 2-8- Patent-level analysis: Relationship between time to IPO and patent life category

	Sub-Model 1			Sub-Model 2		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(60**
Application was in [-5,0] of IPO	-0.4752	**-2.2531*****	-0.4350			
	(0.2991)	**(0.6815)**	(0.3153)			
Application was in [-3,0] of IPO				**-0.6081***	**-1.9909*****	-0.4115
				(0.3425)	**(0.5930)**	(0.3260)
Non-VC		0.2103	0.4891		0.0407	0.2793
		(0.6180)	(0.6197)		(0.6275)	(0.6383)
IPO_5yr*Non-VC			**-2.5122*****			
			(0.8205)			
IPO_3yr*Non-VC						**-2.2165*****
						(0.8183)
Time Elapsed from Patent Application to Grant	-0.0323	0.0630	0.0328	-0.0264	0.0487	0.0181
	(0.0313)	(0.0762)	(0.0802)	(0.0324)	(0.0787)	(0.0823)
IPO Size		-0.0002	-0.0002		-0.0002	-0.0003
		(0.0005)	(0.0005)		(0.0005)	(0.0005)
Age of firm at the Time of Application	-0.0077	0.0253	0.0184	-0.0079	0.0292	0.0232
	(0.0051)	(0.0387)	(0.0385)	(0.0051)	(0.0402)	(0.0394)
Number of Inventors	0.0204	0.0244	0.0241	0.0213	0.0220	0.0219
	(0.0211)	(0.0294)	(0.0289)	(0.0209)	(0.0301)	(0.0297)
Number of IPC	**-0.0496***	**-0.1100***	**-0.1198***	-0.0461	**-0.1035***	**-0.1116***
	(0.0287)	**(0.0623)**	**(0.0626)**	(0.0282)	**(0.0615)**	**(0.0616)**
Assignee Count	**-0.6051*****	**-1.1915*****	**-1.2030*****	**-0.6009*****	**-1.1631*****	**-1.1683*****
	(0.1473)	**(0.4291)**	**(0.4405)**	(0.1442)	**(0.4222)**	**(0.4319)**
Citations Made	-0.0012	-0.0057	-0.0067	-0.0012	-0.0056	-0.0064
	(0.0032)	(0.0069)	(0.0072)	(0.0032)	(0.0070)	(0.0072)
Number of Claims	**0.0061***	**0.0146*****	**0.0143*****	**0.0062***	**0.0154*****	**0.0152*****
	(0.0033)	**(0.0052)**	**(0.0052)**	(0.0033)	**(0.0052)**	**(0.0052)**
patent_firm_yr	**-0.0011*****	0.0034	0.0045	**-0.0011*****	0.0033	0.0043
	(0.0002)	(0.0037)	(0.0036)	(0.0002)	(0.0036)	(0.0036)
Grant year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Cut1	**-2.0717*****	-0.9699	-0.9803	**-2.0560*****	-0.9847	-0.9982
	(0.4096)	(1.0318)	(1.0488)	(0.4021)	(1.0365)	(1.0428)

Cut2	**-1.2127*** **	-0.0049	-0.0060	**-1.1958*** **	-0.0325	-0.0393
	(0.4243)	(1.0284)	(1.0474)	(0.4159)	(1.0321)	(1.0412)
Cut3	-0.4069	0.7992	0.8040	-0.3897	0.7662	0.7644
	(0.4416)	(1.0422)	(1.0631)	(0.4364)	(1.0406)	(1.0513)
Number of Response Levels	4	4	4	4	4	4
N	30,891	6,255	6,255	30,891	6,255	6,255

In all models clustered Robust Std. Err. around assignee in parentheses * p<0.1; ** p<0.05; *** p<0.01

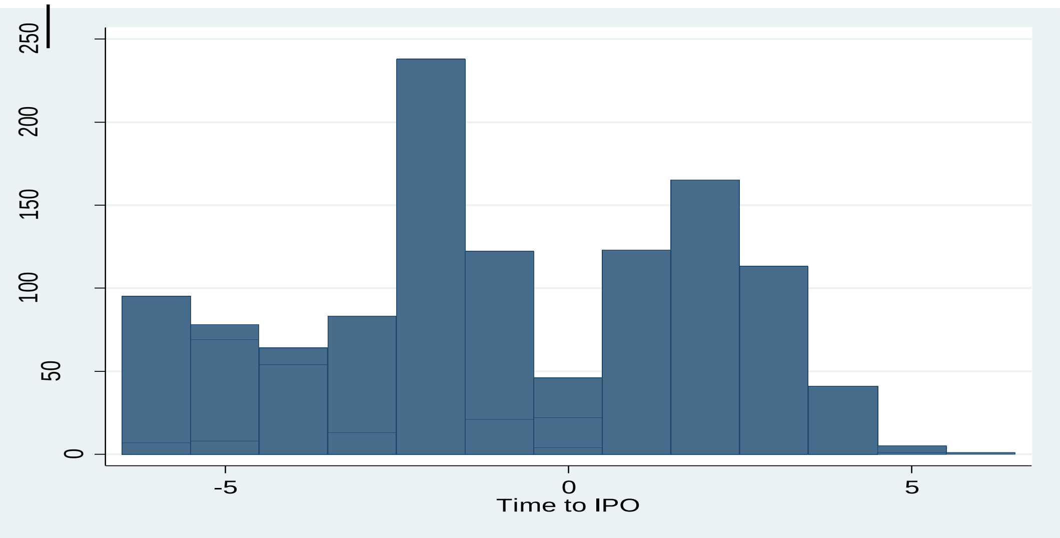
Table 2-9- Patent-level analysis: Relationship between time to IPO and the life of a patent

	Sub-Model 1			Sub-Model 2		
	(1)	(2)	(3)	(4)	(5)	(6)
Application was in [-5,0] of IPO	**-1.7710***	**-6.3576*****	**-2.1816****			
	(1.0202)	**(1.7525)**	**(0.9531)**			
Application was in [-3,0] of IPO				**-2.1379***	**-5.8139*****	**-2.0490****
				(1.1127)	**(1.6454)**	**(0.9767)**
Non-VC		0.7490	1.4433		0.2914	0.8787
		(1.9622)	(2.0737)		(1.9989)	(2.1266)
IPO_5yr*Non-VC			**-5.6012****			
			(2.4864)			
IPO_3yr* Non-VC						**-5.0801***
						(2.5726)
Time Elapsed from Patent Application to Grant	-0.0890	0.1944	0.1055	-0.0710	0.1369	0.0454
	(0.1134)	(0.2359)	(0.2499)	(0.1141)	(0.2468)	(0.2610)
IPO Size		-0.0009	-0.0010		-0.0010	-0.0011
		(0.0017)	(0.0017)		(0.0018)	(0.0017)
Age of firm at the Time of Application	-0.0298	0.0870	0.0662	**-0.0307***	0.0989	0.0813
	(0.0183)	(0.1294)	(0.1325)	(0.0182)	(0.1324)	(0.1343)
Number of Inventors	0.0509	0.0999	0.0945	0.0554	0.0970	0.0930
	(0.0707)	(0.0893)	(0.0877)	(0.0700)	(0.0895)	(0.0878)
Number of IPC	-0.1501	**-0.3793***	-0.3905*	-0.1372	-0.3683*	-0.3774*
	(0.0987)	(0.2008)	(0.2033)	(0.0977)	(0.2016)	(0.2032)
Assignee Count	**-1.8481*****	**-3.4450****	**-3.3923****	**-1.8675*****	-3.4140**	-3.3607**
	(0.4900)	(1.5366)	(1.5345)	(0.4783)	(1.5145)	(1.5103)
Citations Made	-0.0022	-0.0185	-0.0211	-0.0022	-0.0182	-0.0204
	(0.0111)	(0.0213)	(0.0216)	(0.0111)	(0.0216)	(0.0218)
Number of Claims	**0.0225****	**0.0504*****	**0.0494*****	**0.0232****	**0.0530*****	**0.0524*****
	(0.0112)	(0.0144)	(0.0145)	(0.0112)	(0.0144)	(0.0144)
patent_firm_yr	**-0.0032*****	0.0108	0.0135	**-0.0033*****	0.0108	0.0133
	(0.0007)	(0.0118)	(0.0116)	(0.0006)	(0.0117)	(0.0116)
Grant year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	**15.3364*****	**11.0303*****	11.0720***	**15.3097*****	**11.1209*****	11.1742***
	(1.5159)	(3.4971)	(3.5398)	(1.5084)	(3.5186)	(3.5471)
R^2	0.09	0.19	0.19	0.09	0.18	0.18

N	30,891	6,255	6,255	30,891	6,255	6,255

In all models clustered Robust Std. Err. around assignee in parentheses * p<0.1; ** p<0.05; *** p<0.01

Figure 2-1- Average number of patents applied for 5 years prior to IPO to 5 years post IPO and uni-variate analysi



2.8.APPENDIX:

Variable descriptions

Variables	**Description**
Dependent Variables	
Expired /Underutilized	A dummy variable that receives the value of 1 if a patent becomes expired due to failure to maintenance fee was used, and zero otherwise. Once a patent expires, the information contained in that patent claim becomes public knowledge. For each of the patents issued in 1997, 1996, 1995, from ThomsonInnovation database we extracted INPADOC Legal Status, and evaluate whether maintenance fees were paid and how many times were paid. If they maintenance fees were paid three times, it means the patent completed its 20 years life cycle. Similarly twice payment means patent was expired after 12 years and once payment resemble expiration after 8 years.
Expiry Year	All patents in the database were given a value of 4, 8, or 12, corresponding to the year the patent expired due to failure of paying maintenance fees, or a value of 20 meaning the patent did not expire with the assumption that if the 12 year maintenance fee was paid, then the patent will complete its life cycle and lapse at 20 years.
Number of Response	In the ordered Logistic models, number of response represents the number of dependent variable categories. In this study the dependent variable can belong to four categories: category 1 if a patent expires after 4 years; category 2: if the patent expires after 8 years; category 3: if the patent expires after 12 years; and category 4 if the patent does not expire within 20 years after application. Therefore, the number of study in our ordered logistic models is four.
Independent Variables	
Application was in [-3,0] of IPO	A dummy variable that shows whether the application for a certain patent has been submitted within 3 years prior to the applicant's IPO year. It takes the value of 1 if so and 0 otherwise.

Application was in [-5,0] of IPO	A dummy variable that shows whether the application for a certain patent has been submitted within 5 years prior to the applicant's IPO year. It takes the value of 1 if so and 0 otherwise.
Non VC-backed	The assignee did not receive VC funding after 1970. The data regarding VC investments is extracted from VentureXpert (SDC Platinum).
Control Variables	
Age of firm at the Time of Application	The difference between a patent's application year and patent assignee's founding date
Application Year	The year a patent was applied for
Citations Made	The number of citations to other patents (NBER data). Each patent lists references to previous patents. Citations serve an important legal function, as they delimit the scope of the property rights awarded by the patent. The applicant has a legal duty to disclose any knowledge of prior innovations. Citations Made is a measure of the knowledge spillover or patent originality.
Number of Claims	The number of claims a patent makes. This item is extracted from the NBER dataset (Hall et al., 2001). The claims specify in detail the components or building blocks of the patented invention. The number of claims can be indicative of the scope or width of an invention.
Industry Fixed Effect	If receives a value of "yes", it means the model includes 6 dummy variables for industry fixed effect. That is, the model assumes that firms in the same industry are more similar to each other than firms from other industries, and it controls for this similarity.
Founding Year	The year a firm was founded. Extracted from Thompson SDC database.
3 dummies for Grant Year	The year a patent was granted (1997, 1996, 1995 in this study)
IPO Size	The logarithm of Proceeds from IPO in 1997 million dollars. The amount of proceeds from IPO is downloaded from SDC Platinum. Then to control for the time value of money, dollar values are converted into equivalent 1997 dollars. IPO size is a measure of firm market value and also the amount of funding a firm could raise in the market.

Grant time	The time difference between application year and grant year.
Inventor count	Number of inventors (extracted from Thomson Innovation)
Assignee count	Number of assignees (Extracted from Thomson Innovation)
Number of international patent classes	Number of international patent classes (IPC) assigned to the patent which demonstrate how general is the patent.
Number of Patents	This variable represents the number of patents granted to each firm during grant year (1997, 1996, 1995, the basis year in this study). It is counted as the number of times a firm shows up in the database. Each patent has a unique patent number and only occurs once in the database, however each firm number is listed each time they are granted a patent. Number of patents can be a measure of innovativeness or activity in the patenting market.
Clustered for Firm Fixed Effect	If receives a value of "yes", it means the model is clustered for firm fixed effect. Each firm in our sample can have more than one patent granted in 1997, 1996, 1995. The clustered models then assumes that patents that belong to the same firm have more common characteristics than patents from different firms, and it controls for this commonality.
Intercept for not expired/expired at 8/12 years	In the ordered logistic models, these intercepts are the estimated ordered logistics for the adjacent levels of the dependent variable, not expired versus expired at 12 years, and expired at 12 years versus expired at 8 years, and expired at 8 years versus expired at 4 years, respectively. We use SAS to run the ordered logistic models. To identify these models, SAS se the first intercept to zero, that is the intercept for expired at 4 years. For more information see SAS 9.3 manual or read Greene (2003).

CHAPTER 3

3. CHAPTER 3: EARLY TERMINATION OF VC INVESTMENT AND ENTREPRENEURIAL VENTURE'S PERFORMANCE[42]

[42] This chapter is based on Working paper : Mohammadi , A; Shafizadeh, M, Johan, S (2013), "Early termination of VC investment and entrepreneurial venture's performance".

"There is usually pressure from insiders to participate [in the subsequent round of financing], and if you are not investing you need a pretty good reason." (Guler, 2007:257)

3.1. INTRODUCTION

Entrepreneurs seek VC support not only for financial support; but also they look forward to value added services provided by VCs such as professionalizing management team (Hellmann & Puri, 2002). In addition to these first-hand contributions of VCs to success of entrepreneurial ventures, the backing of VCs is a quality signal to the market (Carter & Manaster, 1990; Stuart et al., 1999). VCs are very selective and only finance potentially high growth firms; and in return, VC-backed ventures experience better performance, e.g. they are more likely to go public or get acquired (Gulati & Higgins, 2003).

Further investigation is warranted to study how the involvement of VC, beyond its selective capabilities, sends a quality signal. For instance, reputed VCs produce a better outcome (Hochberg et al., 2007); though reputed VCs require a 10-14 percent valuation discount to start equity investment (Hsu, 2004). This paper explores a new dimension of VC affiliation on entrepreneurial ventures' outcome. Specifically, this paper investigates how early termination of investment in a venture by an existing VC investor negatively influences the prospects of entrepreneurial venture even if the entrepreneurial venture is of a quality grade investable by other investors.

The case of early termination of investment in a venture by an existing VC is illustrated by the pattern of investments in Instagram, a social photo-sharing mobile application venture. Andreessen Horowitz, a Silicon Valley venture capital firm, terminated its participation in the follow-up rounds (e.g. series A, B) after a seed round of USD 250 thousand in Instagram. Facebook Inc. acquired Instagram for approximately USD 1 billion two years later than its seed funding round[43]. Indeed, a cursory observation of typical VC investment suggests that VCs typically re-

[43] In this case, Instagram could have been a higher return investment had Andreessen Horowitz continued participating in series A funding.

invest in subsequent stages of financing unless the venture is perceived to be a case of failure. Specific to Instagram case, Marc Andreessen, the co-founder of Andreessen Horowitz points out "*we (or any venture firm) make(s) an A-round investment, we typically reserve another 2-3x of the A-round investment size for participation in future follow-on rounds for that company. So a $5M Series A shows up on our books more like a $20M commitment. The other $15M isn't necessarily always deployed, of course, but we also double down even more strongly in certain cases (either out of opportunity or sometimes necessity) so it balances out*."[44] Marc Andreessen goes on to point to a conflict developed in the portfolio of their investments after the seed round of Instagram, i.e. Instagram evolved its product and "ended up doing similar things"[45] to another portfolio venture. "This kind of conflict—which happens frequently in the venture capital business as companies evolve"[46], or any other conflict – which results in an investor leaving (money on) the table is the study subject of this paper, a phenomenon we call "VC early termination of investment in a venture".

In this paper, we aim to draw from signaling theory to shed light into how the discontinuation of investment in an entrepreneurial venture by an existing investor conveys a negative signal, resulting in a "side-effect". We argue the side effect is a consequence of the presence of information asymmetry in entrepreneurial financing. Information asymmetry is a prevalent feature of entrepreneurial financing since entrepreneurial ventures have a short track record of performance and lack legitimacy. We find that the decision of potential investors is adversely affected if an investor gives up funding the subsequent rounds of financing, furthering adverse selection problems.

[44] https://news.ycombinator.com/item?id=6530536

[45] http://bits.blogs.nytimes.com/2012/04/20/how-andreessen-horowitz-fumbled-an-instagram-investment/

[46] http://bhorowitz.com/2012/04/22/instagram/

We construct a sample of 5,016 round of VC investment (venture-VC) in 1,728 entrepreneurial ventures that received more than one round of investment. We apply the Heckman two-stage framework to control for the endogeneity of VC early termination and examine the impact of VC early termination on the financial terms and quality of potential investors in the next round of financing. We find that early termination is associated with lower valuation in subsequent round of financing and also reduce the attractiveness of the venture by attracting lower quality potential VCs in its follow-on round of investment.

Our goal is two-fold in this paper; first, we reveal the manifest of negative signal in the subsequent valuation of the venture, which has experienced early termination of investment. We report results in entrepreneurial finance, consistent with Akerlof's prediction (1970). Akerlof (1970) uses the markets for used cars to demonstrate a discount in price is followed by exacerbated levels of information asymmetry. Second, we seek to examine the view held by economists that accreditation of party that originates the signal may moderate the (negative) perception of the signal, ceteris paribus. We find that the prominence of VC leaving the venture and stage specialization of VC are moderating the negative signal of early termination on venture's valuation to different degrees.

This paper contributes to the entrepreneurial finance literature for at least two reasons; First, Our work is a departure from establishing link between the presence of VC and a dichotomous quality signal (Stuart et al., 1999). Since, VC invests in multiple stages and often in syndication, a closer look at how VCs stage financing entrepreneurial ventures in syndication and their decisions in this context progresses our understanding about the signaling value of VC affiliation. Along this inquiry, we intend to show that literature of signaling in entrepreneurial finance is better informed if researchers focus their attention on the interaction of VC syndicate members. This approach, as we argue, yields interesting conclusions with respect to the entrepreneurial venture's outcome, a consequence of particular interest to researchers and practitioners.

Second, we pay attention to the attributes of the involved VC and how these attributes and actions influence the future development of the venture; VCs are heterogeneous in their affiliation, e.g. independent VC vs. Corporate VC, and quality, i.e. experience to take companies public. This heterogeneity is linked to a number of consequent value-adding outputs; for instance, corporate VCs are inclined to pursue strategic objectives rather than pure financial objectives and they can provide corporate resources (Dushnitsky & Shaver, 2009). We highlight how the attributes of involved VCs influences the prospects of the ventures in a new context; a context in which the bargaining power of entrepreneur, and existing investors not leaving the venture, is compromised in obtaining further financial resources from potential investors. Indeed, this context in literature has been neglected so far in our opinion and from this starting point; we hope to encourage researchers to study other aspects of this context.

The paper is organized as following. First, we discuss the background of this paper by addressing first, the foundations of signaling framework in entrepreneurial finance and second, we turn to motivate why an existing investor would want to discontinue investment. Following the background, we develop the theory and relevant hypothesis. Next, we provide the methods including data, variables and the results. We conclude by discussing our findings and the limitations of this research.

3.2.BACKGROUND

Research using signaling theory in the context of entrepreneurial venture has shown the promise and its relevance in a number of contexts such as IPO (Gulati & Higgins, 2003) and acquisition market (Reuer et al., 2012). We proceed by first introducing the signaling framework and second, we paint a picture about early termination of VC investment and when it is more likely to occur.

3.2.1. INFORMATION ASYMMETRY AND SIGNALING

The short track record of entrepreneurial ventures by which the quality is assessable, possess a challenge for the evaluation to investors (Amit et al., 1998). For instance, technology ventures are risky since the development of new technologies is associated with high uncertainty and the market adoption is not yet foreseen and speculative. The uncertainty surrounding the prospect of entrepreneurial ventures may hinder the acquisition of financial resources from investors; since investors only have ambiguous and scarce direct information about the quality of venture (e.g. track record of sales, revenue streams), they rely on observable attributions that are signals of unknown quality. A signal is positively correlated to unobservable characteristics of quality and it is less costly for high-quality ventures to generate than low quality ones (Spence, 1973). Granted these conditions, a quality signal plays a central role in reducing information asymmetry, assisting investors to mitigate adverse selection problem. It is no surprise that entrepreneurial ventures possessing more quality signals are desirable to investors, and are more likely to receive higher valuations (for instance see Hsu and Ziedonis, 2013; Heeley et al., 2007).

Entrepreneurial organizations can convey their quality through a number of mechanisms, which assist evaluators estimate the conditional probability of success given those observable set of characteristics. For example, the ability to patent by a young venture is not only a mechanism to appropriate the rents of invention (the intrinsic value of patent); but also a signal proving the deep technological capabilities of the venture that are outcomes of high quality staff. Hence, patents in high tech ventures are resources performing a dual role (Hsu & Ziedonis, 2013), protecting intellectual property and promoting visibility to potential investors by providing a quality signal.

There are three qualitatively distinct categories of information that influence the perception of quality judgment of young ventures. First, founders' human capital (Dimov & Shepherd, 2005; Cooper et al., 1994) is initially considered a valuable asset and determinant of venture success. Evidence suggests that VCs overestimate the role of start-ups' human capital for the future success (Baum & Silverman, 2004) by attaching considerable selection attention (see Colombo & Grilli, 2010). The second category of relevant information to future investors is related to the previous accomplishment of the firms (Hallen, 2008), be it patents (Hsu & Ziedonis, 2013) or product prototype (Audretsch et al., 2012). For instance, prototype signals the feasibility of the technology and in combination with patents attracts potential investors (Audretsch et al., 2012). Third category of information that evaluators can use to assess the quality of the nascent venture is the attributes of inter-organizational ties (Stuart et al., 1999). Affiliation with prominent strategic alliance partners, well-connected VCs and reputable bank underwriters (Gulati & Higgins, 2003) are positively associated with the quality of the entrepreneurial firm.

3.2.2. VC EARLY TERMINATION OF INVESTMENT IN A VENTURE

When a VC decides to adopt a wait-and-see approach by giving up follow-on investments, it indicates a serious revision of its prior expectations from the venture. Even if other VC firms fund the venture, the shares of the focal VC may severely dilute. As an interviewee in (Guler, 2007)'s work recounts: "*And sometimes that can be real harsh in what comes out. Because what could happen is that if there are four investors and three of them decide to invest in a follow-on round and one doesn't, they can structure it in a way that's remarkably punitive to the one that doesn't participate. Washout round it's called. And that can be pretty painful for [an investor] that has their position wiped out in the new round.*" If the opportunity cost of leaving money on the table is high for the investor, the revised expectation of the focal venture by an inside investor sends a negative signal to the community of VC investors.

Since opportunity cost of early investment termination in a venture is high (e.g. at least, it is the sunk cost of investment), VCs usually escalate their commitment unless they have good reasons not to do so. We articulate a number of speculations around the motivations of an investor that would want to quit a venture: (1) *coercive pressure from limited partners*: VCs are agents of their limited partners and are required to provide (liquid) returns after some finite time. Though, they anticipate their investment time horizon – It typically takes around five to seven years after their first round of investment to experience an exit event (Fenn et al., 1997), the uncertainty around technological development or market adoption trajectory may overshoot their initial expectations. (2) *Portfolio Management*: VCs have a limited fund size dedicated to a (diversified) portfolio of investments. In case, a portfolio firm performs better in a related product market category, they may abandon the underperforming project[47]. For instance, Instagram pivoted[48] and became a competitor with another portfolio firm of Andreessen Horowitz[49]; that's when Andreessen Horowitz decided to stop further investment. (3) *Principal-principal agency problems*: VCs are not homogenous group of investors and may pursue different goals, leading to conflicts of interests, e.g. Corporate VCs are oriented to invest strategically rather than only for financial returns (Dushnitsky, 2006). Goal incongruence of independent VCs with the ones affiliated with banks, corporate, etc. amplifies the agency problems. For instance, Chahine et al. (2012) finds negative performance outcomes (in the IPO context) are brought about if there is more VC syndicate diversity for the firm going public. (4) *Principal-agent problems*: The conflict of interest between entrepreneur and VC may create conflicts of interest. For instance, Entrepreneurs may prefer exit via IPO over acquisition since they enjoy private benefits from being the CEO of a publicly listed company (i.e. investor with strong control rights would affect acquisition over IPO in case of similar financial return when entrepreneurs would prefer an IPO for private benefits) (Cumming, 2008). (5) *Learning of the low-performing quality of venture*: VC investor may come to the conclusion that venture is low quality after it learns more about the venture (e.g. that the venture is failing). Learning is a consequence of VC staging[50]. If VCs learn negative information about the prospects of the venture, the project is

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[47] This is in line with the stream on the sub-additivity of portfolio value, which points that portfolio firms that are closer in technological distance, are less valuable (Vassolo et al., 2004;Yang et al., 2013).

[48] Pivoting refers to a situation when the company changes direction and start over again.

[49] "We were a little bit stuck, He [Mr. Systrom, founder of Instragram] did a pivot into a company we'd already invested in." Mr. Horowitz said. "The context is that we had already invested in Picplz. Once they made changes to their business to compete with them, we couldn't morally go with Instagram." http://bits.blogs.nytimes.com/2012/04/20/how-andreessen-horowitz-fumbled-an-instagram-investment/

[50] Staging of VC is defined as the state-contingent stepwise disbursement of capital designed to mitigate the agency problems. "the most important mechanism for controlling the venture" (Sahlman, 1990:506) is to stage the infusion of capital which is a reflection of the existence of informational asymmetry and agency problems (Gompers, 1995) in

less likely to be financed (Gompers, 1995). So, Early termination of investment in a financing round should reflect the probability of success, conditional on the learning and belief update of VC. Notwithstanding this plausible rationality behind early termination, there is evidence of systematic failure to terminate early investment in ventures, a phenomenon called "escalation of commitment" (Birmingham et al., 2003).

3.3. THEORY AND HYPOTHESIS

3.3.1. VC EARLY TERMINATION OF INVESTMENT AS A NEGATIVE SIGNAL

Academic work in corporate finance has been informative with respect to the relevance of negative signaling to potential investors in the presence of information asymmetry. For instance, a stream of literature on the choice of a firm's finance structure, e.g. debt or equity offering, uncovers why equity offerings are viewed as negative signals, reducing firm's share price (For theoretical discussion, see Leland and Pyle (1977), Ross (1977), Stiglitz (1982), and Myers and Majluf (1984) and for a discussion of empirical evidence, see Asquith and Mullins, 1983). Owners leverage his inside information to issue equity when their shares are overvalued – owners are assumed to know more about firm's prospects than potential lenders or equity purchasers, in turn market reacts negatively to the announcement of equity offerings. On the contrary, when owners/managers believe a bad outcome is less likely, they signal that knowledge by undertaking debt.

A parallel observation can be drawn in the context of early termination of VC investment in a venture[51]. Existing VCs possess private information manifested in their information rights; VCs often demand board rights to monitor their investments (Kaplan & Stromberg, 2003). As such, existing investor has privileged information vis a vis outsiders and his actions convey information about the venture's prospects to potential investors. Anecdotal evidence also reveals this point. "*We*

entrepreneurial ventures. The motivations of staging are, first, if effective monitoring of entrepreneurs is costly, staging is a viable alternative (Sahlman, 1990) and second, staging is a real option that creates value, VC investor acquires information about the quality of the project between rounds and keeps the option to abandon commitment to the project at each round of financing.

51 Abandoning the investment may occur either by early exit/secondary sale to investors or retaining the equity, the latter may appear to be a weaker negative signal. One limitation of our research is that we cannot distinguish between these two types.

spend all the time as a firm managing signaling risk and we had talked to lots of entrepreneurs or other seed investors about whether or not our participation in the next rounds would actually undermine our relationships with entrepreneurs." [52] As this quotation by Jon Sakoda, the co-manager of New Enterprise Associates (NEA)[53]'s seed investment program suggests VCs are concerned with signaling risks as it may jeopardize their reputation and relationships with entrepreneurs.

The signaling risk is not limited to entrepreneurs; it affects potential investors as well. VC investors are keen on the assessments of their peers. Since VCs solicit "second opinion" on the quality of deals when they decide to invest (Manigart et al., 2006; Brander et al., 2002), they are systematically trained to factor into their decisions the views of their peers when it comes to syndication of investments (especially given that existing VCs know more by definition). Would-be-investors give informational weight to their peer review. If an existing investor leaves the syndication, they are induced to discount the value of the new venture. Therefore, early termination is a "strong" and "visible" type of signal to potential investors[54]. There is further evidence in finance literature from the sequential sales of IPO shares supporting the attention given by potential investors to peer expert evaluation. For instance, Welch (1992) develops a model related to sequential sales of IPO shares in which potential investors ignore their private information and imitate earlier investors, a phenomenon he calls "cascading".

From the previous description of the motivations of early termination of investment, at least two reinforcing reasons could be accounted for the expectation that early termination of investment in a venture may adversely affect the performance. First, the early termination from a VC conveys a

[52] http://techcrunch.com/2013/07/12/ask-a-vc-neas-jon-sakoda-on-why-the-venture-firm-makes-seed-investments-and-more/

[53] NEA is one of the world's largest and most active venture capital firms. http://www.nea.com/about

[54] A negative signal is more likely to be undermined if its visibility, or observability, is altered – the strength of a signal (closely mirroring its cost) is not a necessary condition to produce its desired effect, it also has to be visible to the receiver.

negative signal to potential investors, curbing demand and lowering the bargaining power of entrepreneur in obtaining good valuation. Second, an investor may have left for venture's bad performance. If a VC is not convinced of the growth potential (marginal return from continuation of investment), he may leave by foregoing his sunk cost of past investment. The bad performance also takes the form of lower valuation of the company in a subsequent round. This ex ante bad performance may persist even if investors escalate commitment of investment in the venture echoing optimistic beliefs. Therefore, The VC early termination may be endogenous to performance and a proper empirical methodology should address the issue of endogeneity.

Hypothesis 1a. VC Early termination of investment in a venture has a negative effect on the valuation of the focal venture.

There is a fairly robust finding pointing to a positive sorting between entrepreneurial ventures and VCs; Better quality ventures match with reputable VCs (Sorensen, 2007). On one side, entrepreneurs are willing to pay a valuation premium to be affiliated with high quality VCs (Hsu, 2004) and on the other side of table, VCs try to establish reputation, which is an important factor in successful fund raising for new funds (Gompers, 1996). With that said, we expect that the negative signal from early termination to affect adversely the perceived quality, hence attracting less reputable VCs.

Hypothesis 1b. VC Early termination of investment in a venture has a negative effect on the overall reputation of the future investors in the subsequent round of financing for the focal venture.

3.3.2. THE MODERATING ROLE OF ATTRIBUTES OF VC

Although, we control for the quality of the venture and use an empirical method that appropriately addresses endogeneity, the directions of both ex post negative signal and ex ante deteriorating performance is going in the same direction towards a valuation discount. In order to isolate the effect of negative signaling from deteriorating performance, we identify conditions under which early VC termination are likely to act as strong or weak quality signals (differential impact), holding constant venture quality type. Our strategy is to vary the characteristics of VCs who terminate the investment, e.g. reputation and specialization. First, we argue that the quality of ventures on average is high when they are associated with industry and (early) stage specialized VCs or reputable VCs. Second, we show an economically significant difference of the impact of early termination of these types of VCs on the valuation.

Some VCs are specialized in specific stages of the development, geographical areas or industries (Knill, 2009). Dimov & De Clercq (2006) document VCs specializing in a stage of development decrease their portfolio rate of failure. If a fund focuses on early stage investment, it may incur costs if she wants to commit capital in later-stage rounds. Limited partners can punish the focal firm by withholding participation in follow-up fund since such deviation ("style drift") is not aligned with limited partner's preferences (Cumming et al., 2009). As such, it is less likely that VCs specializing in early stage investments efficiently provide second round financing (Schwienbacher, 2013)[55]. On the intersection of stage and industry specialization, Manigart et al. (2006) documents that specialized early stage investors syndicate less often for deal selection purposes than non-specialized early stage investors. Building on this differential preference towards "second opinion" from different investors, we argue that early stage investors, i.e. with more experience in early stage investment, that terminate their investment early produce a less significant negative signal than non-specialized early stage investors[56].

H2. Early termination of investment by a stage specialist VC has weaker negative effect on the valuation of the entrepreneurial venture.

Well-connected VCs (i.e. VC that enjoy central positions in the syndicate network) are able to provide better value-added services and hence, enhance a new venture performance (Hochberg et

[55] Early stage specialist VCs are better (early stage) value adding investors who are reluctant to finance later rounds (Schwienbacher, 2013); however, generalist VCs is weakly positioned to contribute (early stage) value beyond securing follow-up financing. The theoretical framework of (Schwienbacher, 2013) predicts that under asymmetric information of venture quality, entrepreneurs with high (low) quality projects prefer specialists (generalists).

[56] Here we only focus on early stage investment and no hypothesis regarding late stage is developed.

al., 2007). On average, we expect that the performance of entrepreneurial firms associated with prominent VC to infer high quality.

As would-be investors strive to assess the quality of the venture[57], they scrutinize the relationship of the venture with other organizations (Stuart et al., 1999), with special considerations to their reputation. VCs are prominent inter-organizational ties with equity stake. The loss of a prominent affiliation is status decreasing; this is in fact in the reverse direction of the status transfer from forming strategic partnerships with prominent affiliates (Stuart et al., 1999).[58]

H3. Early termination of investment by a prominent VC investor has stronger negative effect on the valuation of the entrepreneurial venture.

3.4.METHODS

3.4.1. DATA SOURCES

We use SDC Platinum database to build the sample of VC-backed entrepreneurial ventures. From all VC rounds of financing in the U.S. from 1980 to 2012, we exclude observations which are not considered as "Venture Capital"[59]. We exclude all observations for an entrepreneurial venture in which at least one investor is labeled "Undisclosed firm". The reason for this exclusion criterion is that we rely on venture capital firm names provided by SDC Platinum to determine if a venture receives financing from an existing investor in its subsequent round of financing. We focus on investments in only two States of California and Massachusetts for the following reason. In the US, majority of VC investments are prevalent in California and Massachusetts[60] and quality signal is found to be more relevant in regions with high density of entrepreneurial activity (and

[57] There are two general types of concern for investors, including VCs: investing in 'bad' deals and missing 'good' opportunities (Gulati & Higgins, 2003). The negative signal may alert them rather toward bad deals.

[58] This negative association is expected to be pronounced for early stage investors since VCs don't mind syndicating with less established firms in later rounds (Lerner, 1994).

[59] SDC platinum categorized the investment in four categories of "Buyout/Acquisition", "Venture Capital", "Real Estate" and "other"

[60] In our sample between 1980 till 2012 more than 50% of observations belong to entrepreneurial venture in California and Massachusetts.

consequently, VCs)[61]. We limit our study to transitions from first round of investment to second round. Hence, we consider early termination of investment only if the name of an investor present in first round is not mentioned in the second round; This filter is applied since the signal effect of early termination is likely to be stronger in the early round when the presence of information asymmetry is acute (Hsu & Ziedonis, 2003; Dushnitsky & Shaver, 2009) – e.g. The more the venture matures, the more likely it is to acquire other endorsement signals and certifications such as positive revenues [62]. The SDC database overstated the rounds of financing and considers any separate investment dates as a new round (Gompers & Lerner, 1999; Guler, 2007; Cumming & Dai, 2012). We correct for this problem by considering the investment rounds that happens in time intervals shorter than 90 days as one round (Guler, 2007). In order to be able to track the exit of entrepreneurial venture, we limit our sample to entrepreneurial venture, which received first round of investment in 2007 or sooner – we allow at least 5 years for exit. After excluding observations with missing data on the amount invested in the second round, applying above filters, we obtain 5,016 round of VC investment in 1,728 entrepreneurial ventures.

3.4.2. MEASURES

3.4.2.1. Dependent Variable: Performance

Amount of money raised in the second round. In this study, we investigate the impact of early termination of investment in the next round of investment. In order to proxy for performance in the second round of financing, we consider the amount of money that entrepreneurial ventures receive in second round (round size) of investment (H1a) (inflated by millions of 2012 dollar) –

[61] Refining classic signaling model of Spence (1973) by introducing changes in the quantity and quality of labor supply, A matching tournament model of a labor market (Hopkins, 2012) shows that increased competition leads to more efficient investment in education under flexible wage. if one takes the VC investments as a market with changes in quantity and quality of supply of entrepreneurial ventures, (having in mind the local bias of VC investments (Cumming & Dai, 2010), we expect that a market (represented with location) with more competitive conditions leads to more efficient investment decisions.

[62] Each additional round is an indicator of progress and a good proxy for performance (Gompers & Lerner, 2001; Mann & Sager, 2007). In our setting since entrepreneurial ventures are able to raise the second round of financing, it indicates a minimum threshold of quality. From this sampling filter, the concern over early termination due to low quality of entrepreneurial venture is alleviated. Hence the entrepreneurial ventures in our sample are more homogenous regarding their quality.

Although a more accurate measure is pre-money valuation, we don't have access to this variable. Higher round size shows better deal terms that entrepreneurial venture has been able to receive (Cumming & Dai, 2012).

Quality of VC. Entrepreneurial ventures prefer to be associated with higher quality VC even if high quality VCs require a premium of about 10-14 percent on valuation (Hsu, 2004). Higher quality VCs add more value and provide stronger certification signal. We use the quality of outside VCs[63] that invest in the second round as a proxy for venture's quality (H1b). The quality of outside VC has been calculated using different proxies.

First, we consider "general experience" (Gompers et al., 2009), the number of rounds in which a VC participated in the prior past five years to that round investment[64] (Sorensen, 2007) since 1980. The VC gains valuable knowledge and expertise about VC market and success or failure of portfolio companies in each round of investment, valuable in selecting promising ventures and coaching them toward success. Second, we calculated the number of entrepreneurial ventures that a VC has taken public in the prior five years ("IPO experience"). It measures the ability of VC to select high quality entrepreneurial ventures, monitor and coach them after the investment (Cumming et al., 2011). Third, VC invests in syndications with other VCs. Participation in syndication allows VCs to get better evaluation. Hochberg et al., (2007) shows the VCs, which have a more central position in network of investors, are able to provide (better) value-adding services to their portfolio ventures. Hence, we use centrality, specifically "eigenvector centrality", of VC firm

[63] Outsider is defined as VC which did not participated in the first round and is facing high information asymmetry in evaluating quality of entrepreneurial venture (Sorensen, 2007). Prior literature shows importance of access to high quality VCs in follow-on rounds. For instance, Cumming and Dai (2012) documented that entrepreneurial ventures with higher perceived quality are more likely to switch to the more reputable VC. While Cumming and Dai (2012) focused on switching of lead investor on deal terms we investigate deeper the dynamic of syndication by looking at early termination by any of investors in the round of investment.

[64] Following Sorensen (2007) we do not consider these variables since for example age does not differentiate between active and inactive investors. Similarly number of companies can be misleading since investments can happen in early stage or late stage. While VC firms which enter in early stages and help ventures to grow gain experiences which can be more relevant in value-added service to the future investments in comparison to VCs which invest in the late stage. VCs that enter in the early stage participate in more investment rounds. Hence, considering number of companies VC invested in, cannot distinguish between VCs which invest from the early stage and VCs that invest only in the late stages.

in syndication network as a proxy for its quality; eigenvector centrality measures the degree to which a VC shares ties with well-connected VC (a detailed description of network analysis and its importance in VC industry is provided in Hochberg et al., (2007)). Finally, we used the "size of fund under the management of VC" from which the investment in the round takes place. The size of fund measures the reputation and past performance of VC since more reputable and more successful VCs are able to raise larger funds (Gompers, 1996).

3.4.2.2. Independent variables

We define early termination of VC investment in a venture when at least one of the investors in the first round does not participate in the following rounds of investment. If the investor temporally does not participate in the second round but returned in follow on rounds, this is not treated as early termination of VC investment in a venture. About 22 percent of all observations have at least one early termination of investment, suggesting early termination is not uncommon in VC investment.

In order to decide if a VC firm is early-stage specialist, we calculated share of prior investment in "Early Stage" and "Seed" in total investment deals VC has made from its vintage year. We consider a VC as early stage specialist if their relative early stage experience is on top quartile of the sample (27%)[65], otherwise a stage generalist ("Specialist early termination VS. Generalist early termination"). In order to identify the prominent VC, VCs are marked prominents if their eigenvector centrality is above mean values of eigenvector centrality in that year ("Prominent early termination VS. Non-prominent early termination") [66] (Gompers et al., 2009).

3.4.2.3. Control Variables

Outside round: Mostly follow-on investment rounds include an outsider – a VC that did not invested in prior rounds, which usually make the largest investment (Lerner, 1994). An outside investor can mitigate the possible conflict between the entrepreneur and insider investors over the

[65] The mean of whole sample is 23.5% and median is equal to 23.6%.

[66] Alternatively we considered general experience of VC. The results are similar.

valuation of venture (Admati & Pfleiderer, 1994). It is argued that valuation of outside round and inside rounds may vary (Broughman & Fried, 2010); rounds with outside investors are more likely to receive a fair valuation. We check whether there is any new VC in new round or not. This variable is a dummy=1 if at least one VC is an outsider in the second round.

Foreign VC: Foreign VC investors (cross-border VCs) (compared to domestic VC) have a different propensity to escalate commitment (Devigne et al., 2013). Hence, the deal that they participate might differ from the deals that do not include foreign investors. We control for a round which there is at least one cross border investor in the second round.

First round Early stage: Early stage investments are riskier (Gompers & Lerner, 1999) since entrepreneurial ventures usually lack a financial performance and require large effort to achieve success. The stage they received first round of investment can show the required coaching and capital in proceeding rounds.

Quality of venture: in order to quantify the quality/performance of entrepreneurial venture, we lack accounting data and therefore, we should resort to ex post measures of quality; Cumming and Dai (2012) propose to calculate the perceived quality of entrepreneurial venture in each round by considering the fitted probability of successful exit. Success is defined as the occurrence of an IPO or M&A by the end of 2012. The success is predicted using entrepreneurial venture stage, location, industry and the natural logarithm of the amount of investment received ($M of 2012) and year of investment.

Age: we control for age of entrepreneurial venture in round of investment.

Syndication size: VC firms usual invest with group of investors – syndicate deals. Prior studies shows syndicated deals have better performance and the size of syndication is related to the diversity and specialization of syndicate investors. Syndication size represents the number of VC firms participated in round of investment (Lerner, 1994). The control of syndication size is necessary since it conduces political pressure on an investors to escalate their commitment (Birmingham et al., 2003; Guler, 2007).

California: Ventures based in California have better access to capital relative to any other States. We control whether firm is located in California or not.

VC type: objectives and investment strategies of VC firms vary depending on their affiliation and governance (e.g. Dimov & Gedajlovic, 2010). VC type is included in the model through four dummy variables (five groups) indicating whether an investor is a private VC, a corporate VC, a bank affiliated VC, an individual (including angel investors) and "Other" (the baseline variable).

Investment Stage: Entrepreneurial ventures depending on their development stage require different amount of capital and coaching. We include 3 dummy variables for whether in the second round they are in "Seed", "Early stage" and "expansion". "Later stage" is the omitted variable.

Industry: Entrepreneurial ventures may vary in term of required capital, coaching and exit in different industries (Gompers & Lerner, 1999). We controlled for industry of entrepreneurial venture using industry classification of SDC platinum (Gompers, 1995). We included indicator variables for 10 industry groups: Biotechnology, Communications, Computer Hardware, Computer Software, Consumer Related, Industrial/Energy, Internet Specific, Medical/Health, Semiconductors. "Other" is the omitted category.

We also control for general market condition by including IPO market condition as number of IPOs in the years of investment. We also include number of VC deals in the year of investment as the number of investment opportunities available. It also includes two dummy variables to account for the booming information technology market in the period 1998-2000 and the market crash due to the financial crisis in the period 2007-2009 (Nahata, 2008). Table 1 provides a list and definition of all variables.

[Table 3-1 about here]

3.4.3. ANALYSIS

In this study we focus on the impact of early termination of investment on the deal term and quality of VC that entrepreneurial venture is able to attract in proceeding round of investment. In all models (*j*) is referring to entrepreneurial venture, (*i*) is representing VC firm.

$$DealTerm_{ij}=\beta_0+ \beta_1 \text{ Early\_term}_j+ B_2 \text{ DEAL}_{ij}+ B_3 \text{ VC}_i+ \beta_4 \text{PC}_j + \beta_5 \text{ Y}_t+ \varepsilon_{ij}$$

(Equation. 1 Second Stage)

The main concern in this model is that VC early termination ($Early\_term_j$) is endogenous to deal term ($DealTerm_{ij}$) and using a simple OLS can lead to biased results. In order to resolve this issue, we use the Heckman treatment two-stage regression. In the first stage, we estimate a probit model to estimate the probability that early termination of investment happens (explained in more detail in the next paragraph). In Equation 1, the deal term ($DealTerm_{ij}$) is dependent on VC early termination ($Early\_term_j$), Deal characteristics, Entrepreneurial venture characteristics, VC characteristics and general market conditions. Deal characteristics ($\boldsymbol{DEAL_{ij}}$) includes outside investor – a dummy=1 if a new VC joined in second deal, foreign VC – a dummy=1 if at least one investor is foreign, number of VCs in the round, investment stage – 3 dummies for whether the second round of investment is in "Seed", "Early stage", "Expansion". The Entrepreneurial venture characteristics ($\boldsymbol{PC_j}$) includes age of entrepreneurial venture in months, quality of entrepreneurial venture, First round Early stage – a dummy=1 if first round was in "seed "or "early stage", California – a dummy=1 indicating the entrepreneurial venture is located in California, Industry - 9 dummies for industry that entrepreneurial venture belongs too. VC characteristic ($\boldsymbol{VC_i}$) include 4 dummies indicating type of VC. Finally, general market conditions ($\boldsymbol{Y_t}$) includes general IPO market condition, VC market condition – one dummy variable=1 if investment was in information technology bubble period and another dummy variable == 1 if investment was in financial crisis period.

From the first stage, we are able to estimate the inverse mills ratios (IMR) and insert it in the second stage as an independent variable. By looking at coefficient of IMR, we can estimate the impact of selection (VC early termination of investment in a venture) on deal terms of subsequent round. The first stage is the following equation:

$$\Pr(\text{Early\_term}_j) = \phi(\beta_0 + \beta_1 \text{ distance}_j + \beta_2 \text{ quality}_j + \beta_2 \text{ DEAL}_{ij} + \beta_3 \text{ VC}_i + \beta_4 \text{PC}_j + \beta_5 \text{ Y}_t + \varepsilon_{ij})$$

(Equation. 2 First Stage)

In Equation 2, the probability of early termination of investment is instrumented by maximum geographical distance (distance_j) between VC and entrepreneurial venture in the first round, the predicted value of entrepreneurial venture's quality (quality_j), deal characteristics of first round ($DEAL_{ij}$), VC characteristics ($\boldsymbol{VC_i}$), entrepreneurial venture characteristics ($\boldsymbol{PC_j}$) at first round and general market conditions ($\boldsymbol{Y_t}$) at the time of first investment.

The choice of instrument, geographical proximity, is first, relevant and second, satisfies the exclusion restriction. The relevancy is motivated by studies that argue geographical proximity between VC and venture reduces information asymmetry and increases the probability of receiving VC financing (Lerner, 1995; Sorenson & Stuart, 2001; Cumming & Dai, 2010)[67]. Proximity allows better monitoring of investments and proximate ventures experience less staging of investment, longer durations between successive rounds (Tian, 2011). The maximum distance among the investors of the first round is inserted in the first stage because this would better correspond to a venture level measure affecting a venture to experience early termination of investment. This measure is significantly correlated with VC early termination for a given venture, but not with the performance measure, thus, it conforms well to the exclusion restriction. To operationalize distance following, we collected data on latitude (*lat*) and longitude (*long*) in radians for each zip code from

[67] The importance of geographical proximity can be applied to any investment. The main reason can be that '*Local investors talk to employees, managers, and suppliers of the firm; they may obtain important information from the local media; and they may have personal ties with local executives—all of which may provide them with an information advantage*' (Cova & Moskowitz, (1999): 2046).

U.S Census Bureau's Gazetter[68] (Cumming and Dai , 2012). Distance is calculated by Great Circle distance equation[69]:

$$d_{ij}=3963 \text{ Arcos}[\sin(lat_i)\sin(lat_j)+ \cos(lat_i)\cos(lat_j)\cos(long_i-long_j)]$$

(Equation. 3 Great Circle distance equation)

The deal characteristics are calculated for the first round including a dummy if the first round is "early stage", a count variable indicating diversity of investors in terms of their affiliation (number of investors types, i.e. Independent VC, Corporate VC, etc that can get a value between 1 and 5)[70]. $\boldsymbol{VC_i}$ includes the age of oldest fund that invested in the first round of investment. $\boldsymbol{PC_j}$ includes a dummy whether entrepreneurial venture is in the California and 10 dummies for industry of entrepreneurial venture. $\boldsymbol{Y_t}$ includes general investment condition variables, including IPO market condition measured as number of IPO filing in the year of first investment extracted from Jay Ritter database. We also consider VC market condition by calculating number of VC investments in the investment year as indicating the supply (investment opportunities). We also includes two dummy variables to account for time variations - the booming information technology market in the period 1998-2000 and the market crash due to the financial crisis in the period 2007-2009 (Nahata, 2008).

From Equation 2, we calculate IMR and insert it in Equation 1 as an additional variable; all the other covariates are calculated from second round in Equation 1.

3.5.RESULTS

From figure 3-1 we can see distribution of Early Terminations, 21.94% of observations are ventures, for whom at least, one of their investors in the first round gives up funding follow-on

[68] http://www.census.gov/cgi-bin/gazetteer

[69] Similar approach was adopted in different investment decisions such as M&A and equity trading (Ragozzino & Reuer, 2011; Coval & Moskowitz, 1999)

[70] VCs are not homogenous group of investors and may pursue different goals, leading to conflicts of interests (Chahine et al., 2012). This measures the extent of differences between investors in the round of investment. Alternatively we use syndication size, the number of investors in the round of investment. The results are robust.

rounds. Early terminated investments are distributed unevenly trough different year with a maximum of 75% in 1980 and minimum of 8.99% in 1981.

[Figure 3-1 about here]

Table 3-2 summarizes the characteristics of entrepreneurial ventures that one of their investors in first round of investment terminated its investment in second round. As Table 3-3 indicates early termination of investment by a venture is more likely to happen to entrepreneurial venture that received second round of investment in "expansion stage", they are mainly in computer software and internet-specific entrepreneurial ventures and they received more money in the first round of investment.

[Table 3-2 about here]

Table 3-3 compares the consequence of early termination of investment. The early termination of investment leads to reduction of round size and also shows reduction in experience of outside investors in the second round measured by general experience, IPO experience, Network centrality and fund size. While the experience is lower in absolute number but it is not statistically significant in all cases. In the next section in a multivariate analysis by considering the endogeneity issue, we further investigate the difference between the two groups. Table 3-4 shows the pair wise correlation matrix.

[Table 3-3 about here]

[Table 3-4 about here]

3.5.1. EARLY TERMINATION OF INVESTMENT AND DEAL TERM

We employ two-stage Heckman selection model to obtain unbiased estimates of VC early termination of investment. In panel B of table 3-5, we predict the probability of early termination of investment using the following covariates: maximum distance between VC firms participated in the first round of investment and the entrepreneurial venture, perceived quality of entrepreneurial venture, stage of investment, diversity of VCs participated in the first round, age of the oldest fund participated in the first round, location, industry and general market condition.

[Table 3-5 about here]

From panel B in table 3-5, we estimate inverse mills ratio denoted by "lambda" and use it in Panel A of Table 3-5. Panel A shows that early termination of investment has a negative, economically large, and statistically significant effect on the round size. The coefficient implies that as the consequence of Early termination of investment the amount of capital entrepreneurial venture are able to raise in proceeding round will reduce by 28.4 percent in comparison with entrepreneurial ventures which are not experiencing VC early termination. On average, this translates into USD 3.77 M (USD of 2012) less in the second round of investment relative to their counterparts.

In addition, several observations are noteworthy in Panel A table 3-5. The size of first round is positively correlated with the second round size. The rounds that involve an outsider are on average larger – indicating that outside investors receive a better valuation. Larger syndicate size is correlated positively with round size.

Table 3-6 shows how VC early termination of investment affects the access to high quality VC in the second round of investment. Hence, we consider the quality of outside investors as the dependent variable. If follow-on round involves an outside investor, the outside investor can help in reaching a fair valuation for the venture (Broughman & Fried, 2012).

[Table 3-6 about here]

Table 3-6 shows ventures experiencing early termination of investment is less likely to attract higher quality VCs, consistent with H1b. The quality of VC is calculated based on several variables, including general experience, IPO experience, network centrality and fund size ($M of

2012). Panel A of table 3-6, Outsider VCs which invest in the second round of investment after early termination of investment have on average made fewer deals in prior five year (54 deals), invested in fewer entrepreneurial ventures that went eventually public (5 entrepreneurial venture), are less central in the network of investors (3%) and have smaller funds under management (26.6%).

The positive and significant correlation of Lambda implies that unobserved characteristics in panel B is positively correlated with the quality of outsider VCs in the second round.

3.5.2. Stage Experience and Early Termination Of Investment

In the second hypothesis, we hypothesized if the VC is a stage specialist (e.g. early stage investor), it is possible that the impact of negative signal of early termination of investment is weaker in comparison with early termination of investment by generalists VC (e.g. VC that invests in all stage). In Table 3-7, we test this proposition by considering only the exit of generalist VC or specialist VC. The size and significance of negative effect of early termination increases for generalist VCs. By early termination of a generalist VC, the round size reduces around 110.4 % and general experience of outsider reduces significantly. The outsider VC on average has made around 128 less deals in prior 5 years, invested in 8 venture less that went public and has 5.2% less centrality[71]. While this impact for stage specialist is much smaller and insignificant in some cases.

[Table 3-7 about here]

3.5.3. Prominent VC and Early termination of investment

In the hypothesis 3, we hypothesized that early termination of investment by a prominent VC confers a stronger negative signal about the entrepreneurial venture and leads to lower deal

[71] We repeated the analysis for fund size of outsider investor the result is similar and exit of generalist VC leads to 67.8% reduce in fund size of outsider investor. For brevity we did not report the results and are available upon request.

terms in following rounds. Table 3-8, the negative impact of early termination of investment by a prominent VC is statistically significant and larger in comparison with a non-prominent VCs[72].

[Table 3-8 about here]

3.6.DISCUSSION

We find that negative information is broadcasted to potential investors from insiders (who hold equity stakes). Discontinuation of investment exacerbates information asymmetry, inducing a discount in the price of venture (Akerlof, 1970). After controlling for venture's quality and the endogeneity of early termination of VC in a venture, the results imply that continued equity commitment of existing investors can act as endorsement that shape the perception of outside investors. As a result of unambiguous or relatively scarce measures of observable quality, quality signals are helpful in mitigating information asymmetry. We suggest that continuation of equity investment relationship is a quality signal, conveying that young companies have been able to earn a positive evaluation (at least from inside investors). In other words, we find that young entrepreneurial ventures face a higher cost of external financing if existing investors stop investing in the next rounds of financing. Future investors, faced with great unobservable qualities of young companies and the uncertainty surrounding their financial prospect, rely on observable characteristics to appraise a company; The continuation of investment by existing investors confers a positive signal about the quality of young ventures and that young ventures, as endorsed by further commitment of capital, are more likely to perform better than otherwise comparable ventures that lack such escalated commitment.

While Li & Chi (2013) study circumstances under which investors are likely to withdraw their investment in a venture (Li & Chi, 2013), these authors focus on VC portfolio related determinants. Our study focuses on the perspective of an entrepreneur seeking financing by highlighting the consequence of VC early termination in a venture. Our work is also closely linked

[72] For brevity the treatment analysis is not reported. The results are very similar to the one in previous analysis.

to studies focusing on dynamics of syndication structure in VC investments. We are aware of one paper exploring the dynamics of syndication, which examines the switching of lead venture capitalists (Cumming & Dai 2012). Cumming and Dai, (2012) assess the antecedents and consequences of switching the lead investor for entrepreneurial venture in subsequent round of financing. However, they neglect principal-principal agencies in VC syndications (Chahine et al., 2012). Therefore, there is a drawback in abstracting the syndication to the lead member.

Our research is limited in the sense that we cannot distinguish between VCs that sell their equity shares or those that retain their shares when they give up funding follow-on rounds. Further research can benefit from this distinction. Further research can shed light on how different types of conflict (which we discussed earlier) may lead a VC to terminate its investment and how each may impact the development of entrepreneurial venture.

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3.8. TABLES

Table 3-1- List of variables

Variables	Definition
Dependent Variable	
Ln (round size)	Natural Logarithm of investment amount in a round (measured in million of 2012 dollar)
VC experience	Number of all rounds VC participated prior funding year
VC IPO experience	Number of companies taken public by VC
Ln (VC fund size)	Natural Logarithm of fund size under management (measured in million dollar)
Independent variable	
Early termination of investment	A dummy=1 if at least one of the investors in first round ,does not invest in the second round
Controls	
Outside investor	A dummy=1 if at least one of investors in the second round did not participated in the first round
Foreign VC	A dummy=1 if at least one of investors in the second round is a non-US VC.
First round Early stage	A dummy=1 if the first round of investment was in seed or early stage
First round size	Natural Logarithm of investment amount in the first round (measured in million of 2012 dollar)
Syndication size	Number of VC firms in the round of investment
California	A dummy=1 if the entrepreneurial venture is located in Massachusetts
VC type	Four dummies for different type of VC "Private", "Corporate" , "Bank" and "Individuals"
Investment stage Dummies	Four dummies for different stage of investment "Seed", "Early Stage" , "Later Stage" and "Expansion"
IPO Market condition	Natural Logarithm of Number of IPO in the investment year
VC Market Condition	Natural Logarithm of Number of VC deals in the investment year
Crisis	A dummy=1 if the investment year is between 2008-2009
Bubble	A dummy=1 if the investment year is between 1999-2000
Industry dummies	10 industry dummies for Biotechnology, Communications, Computer Hardware,

	Computer Software, Consumer Related, Industrial/Energy, Internet Specific, Medical/Health, Semiconductors and others
Treatment	
Distance	Natural Logarithm of Distance between the furthest VC and entrepreneurial venture which participated in the first round in miles
Quality	The predicted probability of successful exits (IPO or M&A)
Fund age	The age of oldest fund in year first round, measure in years
First round diversity	The number of VC types participated in the first round can get value 1-5

Table 3-2- Characteristics of entrepreneurial venture

	Non-terminated (frequency)	**Early terminated (frequency)**	**Total (frequency)**
		Investment stage at second round	
Seed	562 (14.35)	126 (11.45)	688 (13.72)
Early Stage	1,336 (34.12)	250 (22.73)	(1,586) 31.62
Expansion	1,800 (45.97)	650 (59.09)	2,450 (48.84)
Later Stage	218 (5.57)	74 (6.73)	292 (5.82)
		Industry	
Biotechnology	340 (8.68)	81 (7.36)	421 (8.39)
Communications	459 (11.72)	124 (11.27)	583 (11.62)
Computer Hardware	369 (9.42)	128 (11.64)	497 (9.91)
Computer Software	952 (24.31)	301 (27.36)	1,253 (24.98)
Consumer Related	84 (2.15)	14 (1.27)	98 (1.95)
Industrial/Energy	110 (2.81)	20 (1.82)	130 (2.59)
Internet Specific	731 (18.67)	152 (13.82)	883 (17.6)
Medical/Health	427 (10.9)	131 (11.91)	558 (11.12)
Semiconductors/Other	374 (9.55)	136 (12.36)	510 (10.17)
Other	70 (1.79)	13 (1.18)	83 (1.65)
		Location	
California	2,928 (74.77)	808 (73.45)	5,107 (75.69)
Massuchusetts	988	292	1,280
	(25.23)	(26.55)	(25.52)
		First round size($M of 2012)	
	6.26	7.96	6.64
N	3916	1100	5016

Table 3-3- Deal terms of second round of investment

	Non_termination of investment	Early termination of investment	Total
Second round size ($M of 2012)			
	13.53**	12.47**	13.30
N	3916	1100	5016
VC experience			
	166.43**	151.69**	162.57**
N	1533	543	2076
VC IPO exprience			
	12.86	12.07	12.66
N	1533	543	2076
VC eigen vector Centrality[73]			
	.075	.072	.074
N	1414	517	1931
VC fund size ($M)[74]			
N	272.65*	247.79*	266.75
	1043	358	1401

[73] The observations are less for network centrality since we were not able to calculate network centrality for investors priors 1985 due to lack of observations prior 1980.

[74] VentureXpert does not report all fund size; hence, we have missing observations. We run model for general experience and IPO experience for smaller samples, the results are qualitatively similar.

Table 3-4- Correlation Table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1-Round Size	1.000																			
2-Early Termination	-0.016	1.000																		
3-Outside round	0.484	0.067	1.000																	
4-Foreign firm	0.026	-0.002	0.030	1.000																
5-1st round Early stage	0.165	-0.014	0.035	0.030	1.000															
6-First round size	0.391	0.108	-0.006	-0.004	0.208	1.000														
7-Age	-0.103	0.094	-0.052	0.054	-0.005	0.048	1.000													
8-Syndication size	0.434	0.022	0.385	0.004	-0.042	0.148	-0.060	1.000												
9-California	0.073	-0.004	0.044	0.007	0.015	0.003	-0.047	-0.017	1.000											
10-Private VC	0.001	-0.048	-0.071	-0.054	0.027	0.010	-0.026	-0.071	0.044	1.000										
11-Corporate VC	0.083	0.036	0.078	0.079	0.021	0.052	-0.003	0.034	0.030	-0.611	1.000									
12-Bank VC	-0.036	0.025	0.029	0.024	-0.042	-0.020	0.026	0.075	-0.046	-0.580	-0.082	1.000								
13-Individual	-0.057	-0.005	-0.022	-0.022	0.004	-0.046	-0.015	-0.027	-0.004	-0.170	-0.024	-0.023	1.000							
14-Seed	-0.188	-0.034	-0.016	-0.045	-0.322	-0.245	-0.155	0.073	0.009	-0.001	-0.026	0.017	-0.001	1.000						
15-Early	-0.120	-0.093	-0.149	-0.015	0.066	-0.161	-0.199	-0.134	-0.035	0.041	-0.032	-0.036	0.042	-0.277	1.000					
16-Expansion	0.232	0.100	0.163	0.035	0.203	0.302	0.163	0.053	0.031	-0.029	0.045	0.014	-0.038	-0.396	-0.658	1.000				
17-IPO Market	-0.024	0.058	0.048	-0.035	-0.161	-0.136	-0.055	0.057	-0.037	-0.042	0.011	0.050	-0.022	0.120	-0.010	-0.058	1.000			
18-VC Market	0.358	-0.052	0.078	0.070	0.276	0.260	-0.052	-0.123	0.045	0.014	0.053	-0.074	0.021	-0.290	-0.001	0.226	0.020	1.000		
19-Crisis	-0.027	-0.035	-0.066	0.001	0.040	-0.006	0.065	-0.134	0.005	0.046	-0.012	-0.049	0.030	-0.041	0.032	0.001	-0.563	-0.029	1.000	
20-Bubble	0.274	0.023	0.118	0.014	0.060	0.115	-0.103	-0.014	0.022	-0.038	0.068	-0.014	0.002	-0.151	-0.043	0.169	0.341	0.643	-0.106	1.000

Table 3-5- Second Round Size

	Panel A
	Log (Round size) ($M of 2012)
Early Termination	-0.881
	(0.090)***
Outside round	0.913
	(0.031)***
Foreign firm	-0.004
	(0.053)
First round Early stage	0.046
	(0.028)
First round size	0.417
	(0.017)***
age	-0.004
	(0.001)***
Syndication size	0.132
	(0.005)***
California	0.142
	(0.030)***
Private VC	0.174
	(0.070)**
Corporate VC	0.272
	(0.081)***
Bank VC	0.048
	(0.082)
individual	-0.376
	(0.157)**
Seed	-0.537
	(0.064)***
Early	-0.279
	(0.058)***
Expansion	-0.191
	(0.055)***
IPO Market	Yes
VC Market	Yes
Crisis	Yes
Bubble	Yes
Industry(1-10)	Yes

Intercept	-0.125
	(0.154)
lambda	0.107
	(0.057)*
Panel B	
	Early termination
Distance	0.079
	(0.017)***
Quality	0.976
	(0.211)***
Early stage	0.074
	(0.045)
Diversity	0.703
	(0.036)***
Fund age	-0.002
	(0.002)
California	0.104
	(0.049)**
IPO Market	Yes
VC Market	Yes
Crisis	Yes
Bubble	Yes
Industry (1-10)	Yes
Constant	-3.092
	(0.383)***
N	5,016

all models Robust Std. Err. in parentheses * p<0.1; ** p<0.05; *** p<0.0

Table 3-6- Quality of outside investors

Panel A				
	VC Experience	**VC IPO Experience**	**VC Centrality**	**Log(VC fund size ($M))**
Early Termination	-53.951	-4.724	-0.030	-0.266
	(19.975)***	(1.642)***	(0.006)***	(0.164) *
Foreign firm	-35.100	-1.584	-0.015	-0.260
	(11.716)***	(0.964)	(0.003)***	(0.096)***
First round Early stage	3.164	0.844	0.001	-0.041
	(7.211)	(0.593)	(0.002)	(0.059)
First round size [75]	6.567	21.856	0.016	-2.233
	(35.152)	(2.890)***	(0.010)*	(0.308)***
Age	-0.530	-0.039	-0.000	-0.003
	(0.131)***	(0.011)***	(0.000)***	(0.001)***
Syndication size	10.116	0.900	0.004	0.067
	(1.084)***	(0.089)***	(0.000)***	(0.009)***
California	-16.525	-1.032	-0.007	-0.164
	(7.892)**	(0.649)	(0.002)***	(0.065)**
Private VC	42.417	2.020	0.012	0.317
	(16.855)**	(1.387)	(0.005)**	(0.148)**
Corporate VC	-2.728	0.382	0.002	-0.179
	(18.747)	(1.543)	(0.005)	(0.165)
Bank VC	100.504	8.054	0.018	0.317
	(19.344)***	(1.592)***	(0.006)***	(0.166)*
Individual	-51.152	-1.464	-0.021	-0.608
	(43.413)	(3.572)	(0.012)*	(0.400)
Seed	-19.265	-0.032	-0.000	-0.733
	(16.577)	(1.364)	(0.005)	(0.134)***
Early	10.413	0.644	-0.003	-0.406
	(15.049)	(1.238)	(0.004)	(0.122)***
Expansion	-13.419	-1.153	-0.005	-0.169
	(14.011)	(1.153)	(0.004)	(0.113)
IPO market	Yes	Yes	Yes	Yes
VC Market	Yes	Yes	Yes	Yes
Crisis	Yes	Yes	Yes	Yes
Bubble	Yes	Yes	Yes	Yes
Industry (1-10)	Yes	Yes	Yes	Yes
Intercept	116.253	-3.949	0.069	5.939
	(38.293)***	(3.150)	(0.011)***	(0.328)***
Panel B				

[75] Alternatively we used quality the results are robust to choice of control variable.

	Early Termination	Early Termination	Early Termination	Early Termination
Distance	0.078	0.078	0.079	0.078
	(0.023)***	(0.023)***	(0.024)***	(0.025)***
Quality	0.686	0.686	0.733	1.079
	(0.311)**	(0.311)**	(0.317)**	(0.351)***
Early stage	0.034	0.034	0.019	0.005
	(0.069)	(0.069)	(0.070)	(0.074)
Diversity	0.856	0.856	0.904	0.834
	(0.060)***	(0.060)***	(0.064)***	(0.063)***
Fund age	-0.001	-0.001	-0.001	-0.008
	(0.003)	(0.003)	(0.003)	(0.004)*
California	-0.109	-0.109	-0.136	-0.151
	(0.075)	(0.075)	(0.078)*	(0.080)*
IPO Market	Yes	Yes	Yes	Yes
VC Market	Yes	Yes	Yes	Yes
Crisis	Yes	Yes	Yes	Yes
Bubble	Yes	Yes	Yes	Yes
Industry (1-10)	Yes	Yes	Yes	Yes
Constant	-2.939	-2.939	-2.941	-3.048
	(0.286)***	(0.286)***	(0.291)***	(0.315)***
lambda	32.483	2.529	0.020	0.213
	(12.514)***	(1.029)**	(0.004)***	(0.103)**
N	2,076	2,076	1,931	1,838

Table 3-7-Stage specialization and early termination of investment

	Round size	Round size	VC Experience	VC Experience	VC IPO Experience	VC IPO Experience	VC Centrality	VC Centrality
generalist - Early Termination	-1.104		-128.532		-8.436		-0.052	
	(0.114)***		(26.656)***		(2.151)***		(0.008)***	
Specialist- Early Termination		-1.039		55.980		0.988		-0.012
		(0.147)***		(30.568)*		(2.540)		(0.008)
Outside round	0.892	0.916						
	(0.031)***	(0.033)***						
Foreign firm	0.009	0.027	-41.439	-40.001	-1.875	-1.599	-0.018	-0.017
	(0.055)	(0.057)	(12.096)***	(12.728)***	(0.995)*	(1.060)	(0.003)***	(0.004)***
First round Early stage	0.018	0.020	0.257	9.679	0.519	1.478	0.001	0.003
	(0.029)	(0.029)	(7.633)	(7.869)	(0.616)	(0.653)**	(0.002)	(0.002)
First round size	0.436	0.440	-2.667	23.450	18.711	21.665	0.010	-0.003
	(0.017)***	(0.018)***	(36.099)	(37.357)	(2.917)***	(3.103)***	(0.011)	(0.010)
Age	-0.004	-0.003	-0.636	-0.440	-0.043	-0.039	-0.000	-0.000
	(0.001)***	(0.001)***	(0.138)***	(0.147)***	(0.011)***	(0.012)***	(0.000)***	(0.000)***
Syndication size	0.128	0.130	10.402	9.380	0.910	0.878	0.005	0.005
	(0.005)***	(0.005)***	(1.091)***	(1.203)***	(0.090)***	(0.100)***	(0.000)***	(0.000)***
California	0.120	0.200	-29.608	-1.597	-2.185	0.092	-0.011	-0.002
	(0.031)***	(0.032)***	(8.489)***	(8.961)	(0.684)***	(0.744)	(0.003)***	(0.003)
Private VC	0.160	0.219	42.403	55.919	2.171	1.893	0.013	0.016
	(0.071)**	(0.076)***	(17.105)**	(19.233)***	(1.407)	(1.601)	(0.005)***	(0.005)***
Corporate VC	0.242	0.267	-5.612	16.936	0.413	0.569	0.004	0.008
	(0.082)***	(0.088)***	(19.104)	(21.240)	(1.571)	(1.769)	(0.005)	(0.006)
Bank VC	0.029	0.064	88.384	134.445	7.690	9.034	0.017	0.025
	(0.083)	(0.089)	(19.688)***	(21.946)***	(1.619)***	(1.827)***	(0.006)***	(0.006)***
individual	-0.415	-0.236	-45.742	-17.353	-0.456	0.780	-0.015	-0.011

	(0.164)**	(0.162)	(44.187)	(49.527)	(3.633)	(4.125)	(0.012)	(0.013)
Seed	-0.553	-0.593	-20.004	-21.032	-0.444	-1.190	0.000	-0.001
	(0.065)***	(0.070)***	(16.884)	(18.670)	(1.388)	(1.554)	(0.005)	(0.005)
Early	-0.274	-0.314	10.493	3.806	0.839	0.212	-0.000	-0.004
	(0.059)***	(0.063)***	(15.456)	(17.170)	(1.271)	(1.430)	(0.004)	(0.005)
Expansion	-0.173	-0.221	-13.231	-12.519	-1.152	-0.559	-0.003	-0.004
	(0.056)***	(0.060)***	(14.475)	(16.177)	(1.191)	(1.347)	(0.004)	(0.004)
IPO Market	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC Market	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bubble	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry(1-10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	-3.111	-3.742	137.384	-70.324	14.564	15.388	0.190	0.167
	(0.331)***	(0.339)***	(101.781)	(112.740)	(8.307)*	(9.377)	(0.035)***	(0.037)***

Panel B

	Early Termination	**Early Termination**	**Early Termination**	**Early Termination**	**Early Termination**	**Early Termination**	**Early Termination**	**Early Termination**
Distance	0.054	0.131	0.077	0.072	0.077	0.072	0.078	0.079
	(0.018)***	(0.031)***	(0.025)***	(0.040)*	(0.025)***	(0.040)*	(0.026)***	(0.041)*
Quality	1.111	0.459	0.529	0.605	0.529	0.605	0.342	0.593
	(0.246)***	(0.296)	(0.374)	(0.464)	(0.374)	(0.464)	(0.377)	(0.467)
Early stage	0.031	0.173	0.076	0.033	0.076	0.033	0.080	0.020
	(0.052)	(0.064)***	(0.078)	(0.098)	(0.078)	(0.098)	(0.080)	(0.100)
Diversity	0.655	0.672	0.754	0.944	0.754	0.944	0.780	1.029
	(0.041)***	(0.051)***	(0.068)***	(0.085)***	(0.068)***	(0.085)***	(0.073)***	(0.090)***
Fund age	-0.003	0.001	-0.002	0.002	-0.002	0.002	-0.003	0.002
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
California	-0.045	0.481	-0.273	0.371	-0.273	0.371	-0.323	0.378
	(0.054)	(0.081)***	(0.081)***	(0.127)***	(0.081)***	(0.127)***	(0.084)***	(0.132)***
IPO Market	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC Market	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bubble	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Industry(1-10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-2.462	-7.188	-2.030	-7.465	-2.030	-7.465	-1.237	-6.730
	(0.444)***	(0.635)***	(0.646)***	(0.929)***	(0.646)***	(0.929)***	(0.732)*	(1.002)***
lambda	0.549	0.458	69.820	-23.563	4.288	-0.490	0.031	0.010
	(0.066)***	(0.078)***	(15.815)***	(17.277)	(1.281)***	(1.437)	(0.005)***	(0.005)**
N	4,674	4,258	1,904	1,705	1,904	1,705	1,762	1,583

all models Robust Std. Err. in parentheses * p<0.1; ** p<0.05; *** p<0.01

Table 3-8- VC prominence and early termination of investment

	Round size	Round size	VC Experience	VC Experience	VC IPO Experience	VC IPO Experience	VC Centrality	VC Centrality
Prominent VC - Early Termination	-1.318		-57.876		-6.694		-0.040	
	(0.114)***		(29.205)**		(2.429)***		(0.008)***	
Non prominent VC - Early Termination		-0.609		-44.797		-3.444		-0.034
		(0.136)***		(27.530)		(2.266)		(0.008)***
Outside round	0.926	0.882						
	(0.032)***	(0.032)***						
Foreign firm	0.029	0.006	-39.693	-39.476	-1.489	-1.894	-0.017	-0.017
	(0.056)	(0.055)	(12.693)***	(12.211)***	(1.049)	(1.007)*	(0.003)***	(0.003)***
First round Early stage	0.015	0.012	3.724	3.467	1.149	0.669	0.001	0.002
	(0.030)	(0.028)	(7.830)	(7.468)	(0.652)*	(0.614)	(0.002)	(0.002)
First round size	0.451	0.426	48.659	-22.937	24.320	17.137	0.017	-0.005
	(0.018)***	(0.017)***	(39.364)	(34.401)	(3.275)***	(2.831)***	(0.011)	(0.010)
age	-0.004	-0.004	-0.514	-0.574	-0.045	-0.038	-0.000	-0.000
	(0.001)***	(0.001)***	(0.143)***	(0.142)***	(0.012)***	(0.012)***	(0.000)***	(0.000)***
Syndication size	0.128	0.132	9.361	10.420	0.878	0.932	0.004	0.005
	(0.005)***	(0.005)***	(1.137)***	(1.160)***	(0.094)***	(0.096)***	(0.000)***	(0.000)***
California	0.203	0.140	-0.656	-21.680	-0.272	-1.246	-0.002	-0.010
	(0.032)***	(0.030)***	(8.871)	(8.610)**	(0.739)	(0.708)*	(0.003)	(0.003)***
Private VC	0.197	0.179	53.803	45.987	2.050	2.219	0.016	0.013
	(0.073)***	(0.074)**	(18.260)***	(18.053)**	(1.509)	(1.489)	(0.005)***	(0.005)***
Corporate VC	0.287	0.219	9.137	2.326	0.570	0.526	0.006	0.006
	(0.084)***	(0.086)**	(20.243)	(20.123)	(1.672)	(1.660)	(0.006)	(0.006)
Bank VC	0.074	0.010	118.423	103.039	8.754	8.003	0.023	0.019
	(0.085)	(0.086)	(21.014)***	(20.649)***	(1.736)***	(1.703)***	(0.006)***	(0.006)***
individual	-0.285	-0.384	-25.975	-39.871	1.171	-0.655	-0.011	-0.015
	(0.170)*	(0.157)**	(49.428)	(44.638)	(4.091)	(3.683)	(0.013)	(0.012)
Seed	-0.537	-0.643	-14.205	-21.871	-0.143	-1.124	0.000	0.000
	(0.066)***	(0.068)***	(17.719)	(17.918)	(1.464)	(1.478)	(0.005)	(0.005)
Early	-0.273	-0.335	10.831	5.560	0.520	0.758	-0.003	-0.001
	(0.059)***	(0.062)***	(16.149)	(16.529)	(1.334)	(1.363)	(0.004)	(0.005)
Expansion	-0.182	-0.229	-5.583	-16.723	-0.497	-0.873	-0.003	-0.002
	(0.056)***	(0.059)***	(15.019)	(15.745)	(1.240)	(1.298)	(0.004)	(0.004)
IPO Market	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC Market	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bubble	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry(1-10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	-3.029	-3.513	-153.479	117.526	-0.922	25.040	0.129	0.202
	(0.333)***	(0.329)***	(105.282)	(105.390)	(8.727)	(8.685)***	(0.035)***	(0.035)***
lambda	0.577	0.318	33.052	24.548	3.795	1.393	0.025	0.021

	(0.063)***	(0.076)***	(16.829)**	(16.105)	(1.397)***	(1.326)	(0.005)***	(0.005)***
N	4,447	4,485	1,791	1,818	1,791	1,818	1,646	1,699

all models Robust Std. Err. in parentheses * p<0.1; ** p<0.05; *** p<0.0

Figure 3-1- Frequency of Early Termination