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Community Collaboration and Venture Capital Finance

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Abstract

Do entrepreneurial ventures that adopt open business model (i.e., ?Open source?) obtain a different quality of VC financing, and receive a different level of VC governance and monitoring post investment? We conduct the analysis on a sample of 514 software entrepreneurial ventures that received VC funding in 6,555 different deals extracted from VentureXpert. The data indicate entrepreneurial ventures with open business model receive funding from VCs that are more highly industry-specialized; more experienced, had greater IPO success, raised more capital and are more

connected in syndication network. Also, they are monitored more intensively through more frequent staged investment rounds.

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1. INTRODUCTION

High-tech entrepreneurial ventures are characterized by pronounced levels of information asymmetry and uncertainty (Hall, 2002; Hall & Lerner, 2010). Accordingly, their access to traditional sources of financing is limited (Berger & Udell, 1998), hence venture capitals (VC) are considered of crucial importance (Gompers & Lerner, 1999). VCs are active investors, which screen entrepreneurial ventures thoroughly and are involved in monitoring and management of entrepreneurial ventures after investment (Gorman and Sahlman, 1989).

The probability of success based on observable characteristics is a key factor in the VC evaluation of entrepreneurial ventures (Stuart et al, 1999). One of these characteristics is the business model that entrepreneurial ventures adopt to commercialize the technology (Kaplan and Stromberg, 2004). Business model refers to the ways ventures capture and create value from an underlying technology (Teece, 2010). Traditionally technological ventures create value through closed business model (CBM) in which innovation is protected by mean of Intellectual property rights (IPRs) in order to achieve monopoly rents (Barney, 1991). In this model VCs helps entrepreneurial ventures to protect and scale up their projects in order to achieve the super normal profits. However, recently ventures opened up their innovation processes which allow them to access external knowledge sources along with internal ones (Chesbrough, 2003). The new innovation process requires mechanisms that venture should employ to access external knowledge and create value. Chesbrough (2006) refers to these mechanisms as "open business model" (OBM). The OBM differs from the traditional model of value creation, which creates value through isolating mechanism and monopoly rent, in two distinctive features. First, in OBM innovation is a joint effort of external and internal knowledge sources. Second, revealing technology and knowledge is an essential means of collaboration between external and internal knowledge sources (Alexy and George, 2013). The OBM allows ventures by reaching outside boundaries of organization captures and create value through increasing innovative performance (Larsen and Salter, 2006), cutting cost (Lakhani and von Hippel, 2003) and improving the quality of products (Chesbrough, 2003). On the other hand revealing technology and knowledge limit ability of ventures to capture value through traditional appropriability mechanisms (i.e. IP Rights) to the fullest extent. Hence the main concern is the complexity of business model and finding a way to generate a sustainable return from investment in technologies which are freely available (partly or fully) to other players.

The prominent examples of ventures using OBM are open source software (OSS) entrepreneurial ventures (Alexy and George, 2013; Chesbrough and Appleyard, 2007). The novel aspect of OSS

business model is reliance on communities of users in order to support their innovation processes (Bonaccorsi et al., 2006; Dahlander and Magnusson, 2005, 2008; Stam, 2009). OSS business model is associated with complexity and risk due to weak intellectual property protection and a complicated institutional setting (Lerner and Tirole, 2002; Mann, 2006; West and Gallagher, 2006). There are growing numbers of OSS entrepreneurial ventures which are looking for external financing[1]. Anecdotal evidence shows OSS entrepreneurial ventures have been able to attract VCs' attention and capital by acquiring more than $3.6 billion in the period of 1997-2010 (Aslett, 2010). Some VCs consider OSS as a "new ecosystem"[2]. There are VCs who monitor OSS entrepreneurial ventures extensively and look for business opportunities (e.g. North Bridge)[3] or focus entirely on OSS entrepreneurial ventures (i.e. Bastos Venture[4]). Ability to raise VC financing by OSS entrepreneurial ventures constitute an empirical puzzle because it defies importance of strong intellectual property protection in VC financing of high-tech entrepreneurial ventures[5]. In this paper, we study OSS business model in comparison with proprietary entrepreneurial ventures (CBM), which develop proprietary software within the boundaries of the firm and the source codes are not revealed.

Prior research which has explored OBM, by using qualitative and anecdotal evidences speculated benefits of OBM (e.g. Chesbrough, 2006). However, scholars have rarely explored the financing of ventures adopting OBM (see Alexy & George, 2011, for an exception). In this paper, we investigate entrepreneurial ventures which adopted OBM, by asking two general research questions: Does adoption of OBM by entrepreneurial ventures affect the quality of VC financing an entrepreneurial venture obtains? Is governance of the investors different than that of entrepreneurial ventures with closed business model?

We draw our theoretical argument on the risk and complexity associated with entrepreneurial ventures with OSS business model. We argue how challenges in OSS business model system of activity and revenue model cause complexity and risk. These challenges are the consequence of OSS business model peculiar characteristics of community based technology development and lack of reliance on intellectual property (Aslett, 2009, Perr et al, 2010, O'Mahony and Ferraro, 2007; Dahlander and Magnusson, 2008, Lerner and Tirole, 2005). Since OSS entrepreneurial ventures are facing with higher risk and complexity, therefore, marginal effect of quality of VC is larger. On the other hand, high risk and complexity and potential for high return makes high quality VCs more inclined to invest

[1] "Sevin Rosen Funds general partner Nick Sturiale mentions his firm received no fewer than 30 business plans from new open source companies in 2005". http://www.seattlepi.com/news/article/Venture-Capital-Open-source-startups-are-hot-1183525.php#ixzz29xIfFZlp

[2] http://www.businessweek.com/stories/2005-10-02/open-source-now-its-an-ecosystem

[3] http://www.northbridge.com/open-source

[4] http://bastosventures.com/

[5] Qualitative and quantitative studies highlighted the importance of proprietary technology in VC financing (MacMillan et al. 1985, 1987; Mann, 2005, Engel and Keilbach, 2007; Mann and Sager, 2007; Hsu and Ziedonis, 2012).

in OSS ventures since they have a higher risk tolerance and better resources and expertise to deal with complexity.

We draw our analysis based on a sample of 514 North American VC-backed software entrepreneurial ventures extracted from SDC Platinum (VentureXpert), which received the first round of VC investment in the period of 1994-2008. In order to identify OSS entrepreneurial ventures, we have relied on different sources of data (described in detail in the data section). The final sample includes 6,555 dyadic portfolio company (PC)-to-VC, which 2,029 of them belong to OSS entrepreneurial ventures (from 124 OSS entrepreneurial ventures).The data indicate VCs that invest in OSS entrepreneurial ventures have significantly higher quality than VCs invest in proprietary ones. We measure VC quality by industry specific specialization, general experience, IPO experience, capital under management and betweenness centrality[6] in syndication network. Furthermore, we observe OSS entrepreneurial ventures receive VC financing in more rounds. On the other hand, there are no significant differences in syndication size. 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.

This study also contributes to the strand of literature that investigates the relationship between entrepreneurial venture's characteristics and VC investment. Prior literatures studied role of patents (Mann & Sager, 2008; Hsu & Ziedonis, 2008), product market strategy (Hellmann and Puri, 2000), employee growth (Davila et al., 2003), entrepreneur experience and education (Hsu, 2007) and litigation (Cumming et al., 2011). While prior research highlighted importance of business model in VC financing (e.g. Kaplan and Stromberg, 2004), but empirical studies treat entrepreneurial ventures 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.

The paper is structured as follows. Section 2 reviews briefly literature and develops hypothesis. Section 3 describes the sample and the data collection procedure; define the variables and the methodology used in the analysis. Section 4 presents the results of empirical analysis and section 5 discusses the conclusions.

[6] Betweeness centrality represents VCs on whom many others must rely to make connections within the network. Higher betweeness represent ability of VC to bring together VCs with complementary abilities or access to deal flows. More detailed explanation can be found in Hochberg et al, (2007).

2. Theory and Hypotheses

2.1. Open Source Software

Traditionally firms create value through closed business model in which innovation is protected by mean of IPRs in order to achieve monopoly rents (Barney, 1991). Recently a trend is noticed toward opening up innovation process and loosening IPRs in order to improve the innovation process by acquiring knowledge outside firm boundaries (Chesbrough, 2003). There are several sources of external knowledge. A branch of literature on open and distributed innovation has focused on communities of users as a major source of innovation with a focus on open source software development (e.g von Hippel and von Kroug, 2003). In this section, we will provide a brief background of the phenomena and its importance for research.

Proprietary software, which is developed within the boundaries of the firm and the source codes are not revealed, dominated the software development model since 1980s. Recently, OSS phenomenon, that several developers scattered around the globe contribute voluntarily in order to develop software that their codes are available to everybody, attracted attention of scholars and practitioners. The great success of some OSS products such as Linux, Firefox and Apache web server has made OSS as a market trend in the software industry (von Hippel & von Krogh, 2003; O'Mahony, 2003). Sourceforge.net, a single platform for OS projects, has more than 324,000 projects and 3.4 million contributors. The first commercialized open source software was introduced in 1995 (Fosfuri et al, 2008). Ever since not only many entrepreneurial ventures entered the market in order to generate monetary profits from new business models[7] (Gruber & Henkel, 2006), but also large firms released several source codes to the communities (Bonacorssi et al., 2006). A recent survey of 740 executives in the software industry forecasts in 2016 more than 50% of software purchased will be OSS[8].

Firms engaged in community collaboration have two distinctive features: "the use of collaborative development structures that extend beyond the boundaries of a single firm and the lack of reliance on *intellectual property ("IP") rights as a means of appropriating the value of the underlying technologies"* (Mann, 2006). The former helps firms to access knowledge which otherwise they were not able to acquire. Consequently they can generate high quality technology and products (Lerner and Tirole, 2002, 2005). Additionally collaboration with community of users reduces the cost of innovation since firms are able to utilize resources outside firm's boundaries with significantly lower marginal cost (Chesbrough, 2003, 2006; von Hipple, 1988, 2005; Lakhani and von Hippel, 2003). In other words, by using external sources of knowledge a firm can monetize an innovation without

[7] Red Hat Inc., a global leader in providing open source solutions to commercial customers, reported revenue of $297 million for the fourth quarter of 2011, 21% increase from last year quarter (http://www.verticalnews.com/premium_newsletters/Investment-Weekly-News/2012-04-14/3574IV.html).

[8] http://northbridge.com/2012-open-source-survey

incurring the complete cost of development (West, 2006). Also, active participation in community collaboration gives firms visibility and assist to build a technical reputation (West, 2007). Aslett (2009) provide evidences that practitioner notice benefits of OSS business model as lower development and distribution cost, reduced sales cycle and better-quality software.

Due to mentioned characteristics of OSS business model, it appears that well-known issues of market entry barriers, smallness and newness are less relevant for OSS entrepreneurial ventures (Henkel and Gruber, 2006). These characteristics raise other challenges and complexities which should be addressed for achieving success[9]. In the following section drawing on prior literature we highlight challenges and complexity of open source business models.

2.2. Open Source Business Model

The recent surge on importance of business model in economic and management literature lead to several studies trying to provide a definition of business model (for a summary of literature see Zott et al, 2011). In this paper we resort on these studies and define business model as "the way firm operates to create and capture value" (Teece, 2010) and focus on two dimensions of OSS business model: system of activities (Amit & Zott, 2001) and revenue generation model (Teece, 2010) which differentiate it from traditional proprietary models.

An important feature of OSS business model is collaboration with community of developers with no contractual ties to the focal firm. This peculiar characteristic engenders additional complexity to the system of activities of entrepreneurial ventures. The OSS entrepreneurial ventures need to use other forms of coordination (rather than formal means of control and bureaucratic governance) in order to align community with the strategic objectives of the firm and to avoid discontinuity in the project[10] (O'Mahony and Ferraro, 2007; Dahlander and Magnusson, 2008).

A broad range of community collaboration models exist. Entrepreneurial ventures can choose to play an active role in community and contribute to development of open source projects directly[11], for example by allowing the employees to spend (fully or partially) time on development of open source projects or by hiring the most prolific developers in the community (Sponsored developers) (Dahlander and Wallin, 2006). Sponsored developers provide visibility and access to the development

[9] Aslett (2009) based on a survey of 61 representatives from investment firms summaries the top risk of OSS entrepreneurial ventures as following: the difficulty in converting downloads to paying customers (57.4%), difficulty in generating revenue (47.5%), lack of intellectual property controls (44.3%), lack of barriers to direct competition (41.0%), lack of control over the future direction of development (32.8%).

[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 stop in the Mambo project in 2008 (http://royal.pingdom.com/2008/09/11/10-interesting-open-source-software-forks-and-why-they-happened/).

[11] This is possible by initiating a new community or contributing to existing ones (Dahlander, 2007).

process and informally influence the project (O'Mahony and Bechky, 2008).The managerial challenge in this model is to be able to respect norms and values of community, obey license and getting acceptance of community (Dahlander and Magnusson, 2005). This is possible by use of democratic and pluralistic mechanism in the governance of communities (O'Mahony and Ferraro, 2007; O'Mahoney and Bechky, 2008). Entrepreneurial ventures such as SugarCRM, SleepyCat and JBoss can be categorized in this section (Perr, et al, 2010). Alternatively ventures can use available codes developed by community without any significant contribution to the core OSS project. Dahlander and Magnusson (2005) refer to this approach as parasitic, which can lead to negative image in community and even create conflict with community which perceives the venture as a free rider. This can endanger a sustainable business model. O'Mahoney and Bechky (2008) identified major challenges which can lead to divergence between ventures and the community. The main challenges are while entrepreneurial venture would like to align community with their strategy and timetable and improve predictability in the software development, the community prefers to maintain communal form, working norms and individual technical autonomy. This issue can be crucial for entrepreneurial ventures which require raising money and this is possible only by committing to provide a road map or milestones (O'Mahoney and Bechky, 2008).

As regard to the revenue generation models, a wide array of real world OSS business models exist (Perr et al, 2010; Alexy and George, 2013; Aslett, 2009). In this paper we focus on two main categories of "selling complementary products and service" and "dual licensing".

In the former company collaborate in the development of OSS in order to increase the demand for their complementary products /services[12]. The major example of this one is Red Hat which monetize on providing supports and updates for Linux. The wide diffusion of Linux will increase the demands for Red Hat services. This can be done also by sales of hardware which use OSS. In this case profit is generated through sales of hardware while use of OSS can assist to reduce development cost. The interesting examples of this case are entrepreneurial venture which use the Linux operating system that are tailored for devices such as mobile phones and machine controls (Gruber and Henkel, 2006).
The main challenge here is to manage the complementarities between OSS and product/service. This implies that entrepreneurial venture require to manage this relationship in order to sustain complementarity of OSS with their product/services in order to be able generate return from OSS technologies which are characterized as weak appropriability regime (Teece, 1986). This is problematic since venture does not have control over OSS community. The change in direction of development in OSS community can fade away the complementrarity of product/services which venture provides. Moreover ventures should provide complementary product/services (high quality)

[12] Complementary Product/Services can be a wide range of offering such as Professional services/consulting, support or devices (Perr et al., 2010).

which are not fully competitive. Since in the fully competitive market they cannot extract super normal rent from their product/services. This is also relevant for community since it provides incentives for the venture to sponsor the community (Katz and Shapiro, 1994). Hence they need to protect their complementary product/service. In case of hardware the situation is similar to proprietary ventures since they can use IPRs. While if the venture provides services, it cannot be protected by means of IPR. In the latter the venture must use strategic means for protecting its competitive advantage (Cohen et al, 2000). Methods such as network effects, lead times, first-mover advantages along with access to complementary assets, are more valuable for this OSS entrepreneurial ventures (Dahlander and Magnusson, 2005, Bonaccorsi and Rossi, 2003).

The dual licensing model refers to differentiating the licenses of product for different customers (Perr et al, 2010; Alexy and George, 2013). It is very similar to versioning where a free version is available to individuals and a premium version is available for companies (Shapiro and Varian, 1998a). The examples of entrepreneurial ventures that adopted this model are MySQL and Sleepycat (Goldman and Gabriel, 2005; Perr et al, 2010). Customers are able usually to self select by freely downloading OSS. The challenge is transferring self selected customers through free downloads to paying customers (Perr et al, 2010, Aslett, 2009). The second challenge is to manage network externalities between the free version and premium version of the software (Shapiro and Varian, 1998b). This implies that value of premium version to the customers increase by number of people using free version (Gandal, 1995). Since wider user networks of free versions provide testing and feedback which consequently improve quality of product and also facilitate exchange of file and know-how with larger crowd (Bonaccorsi and Rossi, 2003). In addition wider diffusion of free version as a core can create indirect externalities (Farell and Saloner, 1985). This implies improving compatibility of premium version with other applications which are developed based on the OSS core. The compatibility increases the value of premium version to adopters (Katz and Shapiro, 1994) and increase probability of self-selection in premium version (Gandal, 1995). Hence in this model network externality implies that not only ventures need to match low quality/low price (differentiation with premium version) for free version but have to encourage people to use the free version in order to increase value of premium version. Since entrepreneurial venture has limited control over community, the change in direction of community can endanger venture sustainability in two ways. First community can improve quality of the free version significantly that premium version has no additional value to the paying customers. This is important since differentiating between free version and premium version is a key factor for creating demand for premium version (Shapiro and Varian, 1998a). On the contrary community can reduce the quality of free version so that it diminishes the network externalities. This can lead to reduction in demand for premium version and increase in the development cost.

In summary, even though OSS entrepreneurial ventures are able to generate high values by producing high quality products with lower cost, but they are associated with complexity in generating revenue from these products. On the other word, while OSS business model in comparison with proprietary has better value creation due to access to a large community of developers, it has inferior value capture since technology is freely available (partly of fully) (Casadesus-Masanell and Llanes, 2011). Alexy and George (2013) by using a legitimacy lens show involvement in OSS business models (measured as the announcement of OSS) which diverge from existing categories, lead to negative reaction of investors due to higher uncertainty.

2.3. Research Hypothesis:

The growth of OSS as a new ecosystem attracts attention of industry analysts and VCs which are focusing on OSS entrepreneurial venture and looking for business opportunities (e.g. North Bridge, Bastos Venture, and The 451 Group).The distinct characteristics of OSS entrepreneurial ventures, which are associated with high risk and complexity from one side and potential high return from the other side, make them attractive for VCs (Gompers and Lerner, 1999). In the section drawing on finance and management literature, we argue why we expect different quality and governance in VC investment in OSS entrepreneurial ventures and proprietary ones.

2.3.1.VC quality[13]

Prior research shows VCs not only provide capital to entrepreneurial ventures but also create value for entrepreneurial ventures through active monitoring and coaching (Ueda, 2004; Sapienza et al, 1996, Sapienza, 1992; Gompers and Lerner, 1999; Gorman and Sahlman, 1989 and MacMillan et al, 1988). VCs are not homogenous in their monitoring and coaching ability and with respect to the value which they add to an entrepreneurial venture (Sahlman, 1990, Hsu, 2006). Higher quality VCs can add value to entrepreneurial firms through three mechanisms. First, VCs add value by better monitoring and coaching. Second, through access to a larger network of suppliers, potential customers and executives (Hellman and Puri, 2002; Hochberg et al, 2007). Finally, since there is substantial information asymmetries about entrepreneurial venture, the quality and reputation of VC can be used as a signal of quality to the outside market and investors (Megginson and Weise, 1991). Therefore in the search for potential investors, entrepreneurial ventures will look for high quality investors (Bygrave and Timmons, 1992; Hsu, 2004; Sorenson, 2007). Hsu (2004) provides evidence that entrepreneurs are willing to give up higher value offers in order to work with higher quality VCs. By

[13] In this paper we refer to VC quality to all dimensions which can distinguish a VC from its peers regarding value added such as experience (general and industry), capital under management, success and network centrality.

looking at a hand-collected sample of entrepreneurial ventures, which received more than one financing offer, he shows offers by high quality VCs are 3 times more likely to be accepted while high quality VCs can acquire equity in entrepreneurial ventures with 10-14% discount.

It has been shown values added by VCs are more valuable for entrepreneurial ventures which are at the early stage[14] (Sapienza and Timmons, 1989; Timmons and Bygrave, 1986) and involve greater in innovation (Sapienza, 1992; Hellmann and Puri, 2002; Tian and Wang, 2011). These finding verifies access to high quality VCs are particularly valuable for entrepreneurial ventures which are associated with higher risk and complexity. Therefore, we can expect since the managing the complexity and risk associated with OSS business model require new organizational routines and managerial capabilities (Bonaccorssi et al, 2006); the marginal effect of VCs quality and value added they provide is larger. For example, complementary assets and speed to market play vital roles in the success of OSS entrepreneurial ventures, therefore, the networks, strategic input and managerial expertise of VCs matter more for them. On the other hand since these is a new and complex business model and suffer from lack of legitimacy as a reliable business model (Alexy and George, 2013) the marginal effect of VC's quality signaling is more significant in comparison with entrepreneurial ventures that develop a proprietary technology. Hence if we consider two entrepreneurial ventures with the same initial value of q, the marginal effect of VC quality is larger for the one with OSS business model (β) in comparison for proprietary one (α). It implies the post-money value of entrepreneurial venture (Sorenson, 2007) with OSS business model conditional on receiving high quality VC (βq) is larger than value of proprietary entrepreneurial ventures (αq). Therefore OSS entrepreneurial venture are able to offer larger share of their venture to VC in the hope of future value and attract high quality VCs. Additionally, since the OSS business model require managerial abilities which low quality VCs lack, they are not able to add value to OSS entrepreneurial ventures. Therefore they will self select into less complex entrepreneurial ventures (in this case proprietary).

Another dimension is related risk associated with OSS business model. VCs evaluate risk and return associated with an investment opportunity and decides whether to invest or not. In the context of VC investment under severe uncertainty can be claimed that VC's resource endowment and expertise can adjust risk tolerance of VC firms positively (Tian and Wang, 2011). On the other word the preferred level of risk, change by VCs' quality. Therefore, high quality VCs are more likely to invest in entrepreneurial ventures which are associated with higher risk and complexity (Ruhnka and Young, 1991). There are two main reasons for the aforementioned argument. First, VC's quality will allow them to raise further fund despite possible disastrous performance of high risk portfolio firms (Gompers and Lerner, 1999). Additionally, it has been shown that expertise and experience can assist

[14] Prior literature based on surveys verifies that risk of loss is significantly larger for early stage firms by ranging between 70%- 53% (Ruhnka and Young, 1986; Wetzel, 1981).

VCs in controlling risk (Gupta and Sapienza, 1992) in addition to gaining access to networks and information (Bygrave, 1988). This implies regarding risk, high quality VCs have similar characteristics of risk neutral investors where expected utility of the investment is equal to the expected value of the investment (Varian, 1992) while low quality VCs are risk averse. Since the OSS entrepreneurial ventures are riskier in comparison with their proprietary counterparts we would expect high quality VCs are more likely to invest in them. Quality can also increase the likelihood of the success[15], the return on investment and reduce the risk of failure (increase the expected value of investment).

Saying that we can conclude, because OSS entrepreneurial ventures are facing a high risk and complexity and are more demanding in case of managerial skills, it is more likely that they receive investment from VCs with higher Quality. Overall, the aforementioned arguments suggest the first hypothesis:

H1: Entrepreneurial ventures with OSS business model are more likely to receive financing from higher quality VC investors.

2.3.2. VC governance

VCs in order to deal with the intrinsic risk associated with entrepreneurial ventures and minimizes downward risk of investment, use governance practices such as syndication and staging (Gompers and Lerner, 1999; Sahlman, 1990; Trester, 1998).

Staging**:** A well-known feature of VC investment is staged financing and preserving the option to abandon the project rather than upfront investment of all required capital (Sahlman, 1990). Staging more frequently allows VCs to monitor entrepreneur efforts and actions, reduce agency cost (Gomper, 1995) and downward risk by avoiding inefficient continuation through the exit option (Wang and Zhou, 2004; Li, 2008). Value of this option is highly correlated with risk of investment (Li, 2008). Gompers (1995) in the light of agency theory showed a decrease in industry ratios of tangible assets to total assets, higher market-to-book ratios and greater R&D intensities is associated with more frequent monitoring through staging. The prior literature verified impact of staging on efficiency of investment decisions and improvement of outcome (Tian, 2011; Kaplan and Stromberg, 2003, 2004). Bergemann and Hege (1998) discussed the impact of staged financing on reducing information asymmetries and learning true potential of ventures. This implies that in each round VC can learn more about the entrepreneur and his/her venture, therefore can make better investment decision to continue funding or abandon the project.

[15] "value-added often provides the margin of success over failure" (Chapter 9,Bygrave and Timmos,1992)

The risk and complexity associated with OSS entrepreneurial ventures can lead to greater uncertainty about returns of investment. Therefore, high risk associated with investment increase value of the option to abandon the project and consequently the likelihood of staging.

H2a: VCs that finance entrepreneurial ventures with OSS business model are more likely to provide intensive monitoring and governance through more frequent staging.

Syndication: Another prominent feature of VC investment is syndication where two or more VCs enter to a deal. In the period of 1980-2005, about 70% of VC investments in entrepreneurial ventures were syndicated (Tian, 2012). Syndication is a common practice in any investment and is not limited to VC financing. For example, any joint venture can be considered as syndication. Sah and Stiglitz (1986) provided a model which reveals two separate evaluations are preferable in the decision process. Sah and Stiglitz (1986) have not considered venture capital finance, but their model can explain syndication of VCs to some extent (Brander et al, 2002). Scholars have provided two main motives for syndication in VC investment: risk sharing through portfolio diversification and resource and information sharing by accessing information and resources which they might not have themselves (Bygrave, 1987; Gompers and Lerner, 1999). Lerner (1994) showed experienced VCs syndicate first round of investment with experienced peers. In the first round of investment information asymmetry and uncertainty about the return is high, therefore syndication will help to reduce the risk and access resources for better screening and coaching. Brander et al (2002) by studying Canadian VC investment provided supporting evidence in favor of value added and risk sharing hypotheses.

In view of the exacerbated risks, uncertainty and business complexity with OSS entrepreneurial ventures, we expect that VCs financing such ventures will provide investment through syndication. Because the syndication will allow VCs to reduce downward risk of investing by spreading it among inventors and can add value and help to deal with complexity and uncertainty by bringing together more expertise and resources (Brander et al, 2002), This proposition is formally stated as the following hypothesis:

H2b: VCs that finance entrepreneurial ventures with OSS business model are more likely to provide intensive monitoring and governance through syndication.

In this subsequent section of this paper, we empirically investigate developed hypotheses by examining the quality of VC finance and VC governance post investment.

3. Data and Methodology

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 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 of information. 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 the word "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" report (Aslett, 2009, 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). 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.

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[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.

[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".

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

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 i) and ii). 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. 2,029 of these dyads refer to OSS entrepreneurial ventures while the remaining 4,526 refer to proprietary software entrepreneurial ventures.

3.2. Variables

3.2.1. 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).

3.2.2. Dependent Variables

VC quality: It is agreed that the quality of VC firms is quite heterogeneous, with some VC firms having better screening, monitoring and coaching ability because of greater investment experience. Accordingly, the first set of dependent variables measures the quality of VC investors through several proxies of their investment experience. [20]

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[21]. Since each VC round involves interaction with and evaluation of entrepreneurial ventures, in each round VC firms acquire

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

[20] 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 and 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.

[21] 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 and Lerner, 2001).

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 of VC firms to select high quality entrepreneurial ventures and/or to monitor, coach and position them after the investment (Cumming et al, 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[22]. 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.

Governance: We considered the governance of VC investment as reflected by use of staging and syndication. The VC literature has documented that in order to minimize downward risk and create efficient incentives for entrepreneurs, VC firms give portfolio companies funding in several rounds of financing rather than as an upfront investment of the entire required capital. This practice allows them to preserve the option to abandon the project if the entrepreneurial venture fails to reach

[22] 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 Σj bij (Hochberg et al., 2007). The results are qualitatively similar. They are not reported in the paper and are available upon request.

the agreed milestones (Sahlman, 1990; Gompers, 1995). 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 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).[23]

3.2.3.Controls

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). 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 and Gelajdovic 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.

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 and 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 and Sager, 2007). When the information imperfection exists, the patents matter more as signal of quality (Hsu and Ziedonis, 2011). 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

[23] Some previous studies on syndication measure the size of the syndicate with the number of VC firms that invested in the focal entrepreneurial venture[23] (Sorenson and 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.

is justified since application is closer to innovation time and patenting procedure can take several months (Hsu and Ziedonis, 2011; Tian and 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 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)[24]. 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 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 and 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 and 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 and Lerner, 1999; Sorensen, 2007; Nahata, 2008; Tian, 2012).

3.3. Descriptive Statistics

Table 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.

[24] 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.

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 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 and 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 governance 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 2 about here]

3.4. Empirical Methodology

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.

3.4.1.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. We analyze this in 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). Since in our sample we have several observations belonging to an entrepreneurial venture we cluster errors around entrepreneurial ventures.

3.4.2.Governance

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

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

In this setting GOV_{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 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 3 reports the pair wise correlation of all variables in both models.

[Table 3 about here]

4. Results

4.1. VC quality

Table 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 control variables which control for VC characteristics; five dummy variables indicate whether investor is Private VC, Corporate VC, Bank affiliate VC, Individuals or other type, 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 or not, two dummy variable indicating whether entrepreneurial venture is in California or Massachusetts and three dummy variables indicating the sub-sector of entrepreneurial venture and number of patent application prior funding. We also control for deal characteristics which are whether it is first round of investment or not and age at the round of funding. Additionally, we control for macroeconomics variables which can have impact on VC investment. We include number of VC deals, the return on S&P 500 index, a dummy whether year of investment is in information technology bubble (1998-2000) and a dummy for financial crisis (2007-2009).

Models 1, 2, 3, 4 and 5 indicate that the OSS entrepreneurial ventures are associated with higher quality VC, consistent with H1. Higher quality is identified through 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 the model 1 the effect is significant at 10% level. While in model 2, 3, 4 and 5 effect is significant at 1% level. 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 have 3.63% higher industry specialization. Similarly have 25.59 more IPO exits which imply VC firms that invest in OSS entrepreneurial ventures have on average 35% more IPO experience in comparison with 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.

[Table 4 about here]

Regarding other variables, we can observe impact of patent on quality of VC firm. This is in line with finding which shows impact of intellectual property rights on VC investment (Mann and Sager, 2007;

Hsu and Ziedonis, 2011). As it was 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.

4.2. Governance

As it was argued above (H2a and H2b), in order to analysis the governance of VC investment we use two variables of number of rounds VC funding was given to entrepreneurial venture and syndication size. Since the number of rounds is measured as total number of VC investment firm 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)[25]. Empirical results in model 1 and 2 show OSS entrepreneurial ventures receive VC funding in more rounds. 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 still pointing in more rounds of investment for OSS entrepreneurial ventures. The coefficients in both models are statistically significant at 1% level. The coefficient in model 1 implies that OSS 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 ones. The Model 3 and 4 verifies that there are no significant differences among OSS entrepreneurial ventures and proprietary ones. We cannot claim any support for H2b.

[Table 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.

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

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 de noted by a value equal to 1 of the dummy OSS 1. We put the rest of entrepreneurial ventures which we were able to identify at least one open source product for them in the separate group (OSS2). While the coefficient in most of models is larger for OSS1 which their business model is entirely based on OSS. The test of difference between coefficients of OSS1 and OSS2 shows there are no significant differences between both groups. Appendix 2 reports the model for quality of VC and governance.

Secondly, Fosfuri et al (2008) shows that endowment of intellectual property of venture impact its decisions on releasing OSS products. Hence, we divided OSS dyads to 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 filed any patents prior to investment (OSS no patent). Similar to previous robustness check the test of difference shows there is no significant differences between two groups. Appendix 3 reports the result for VC quality and governance.

Propensity Score Matching: in the empirical setting we compared the entrepreneurial venture based on whether they develop product with collaboration with community of users or not. In order to ensure that the non-randomness of the sample does not bias results toward the conclusion, 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 while 101 of them are OSS. The results of univariate analysis on matched sample (Appendix 4) confirm 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 syndication, consistent with H2a and H2b. The results are not only significant statistically but also economically. While by controlling for confounding factors in Appendix 5 we can see that results are qualitatively similar to analysis of full sample in previous part (Supports for H1 and H2a but no support for H2b).

One might argue that they are unobserved heterogeneity in the quality of entrepreneurial ventures. In other word, 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 business opportunity they offer. Even though the quality of entrepreneurial ventures is uncertain and hard to evaluate ex-ante, we assume that they are observed factors such as quality of entrepreneurial team, technology and business opportunity which to some extend can predict the success of entrepreneurial venture. Therefore, we control for quality of entrepreneurial venture, measured by successful exit, (Merger and acquisition & IPO). The results support H1 and are qualitatively similar. The results are not reported and are available upon request.

Endogenity check: since selecting to be OSS or proprietary for an entrepreneurial venture is not random, endogeneity may be a potential problem. First following Vella and Verbeek (1999) by using instrumental variables and Heckman treatment model in estimating VC quality (in appendix 7 we explain the models formally) we control for endogeneity. 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[26]. The logic here is the driving forces of open source entrepreneurial ventures are highly skilled individuals in programming and software development. We resort on this idea that the highly skilled programmers can be found among PhD graduates and self educated hackers. 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 report the result of instrumental variable and Heckman treatment model for general experience of VC[27]. 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, by control for endogeneity the coefficient of main dependent variable increases.

Alternatively we use a switching regression model. In this model VC quality are allowed to differ according whether entrepreneurial venture is OSS or proprietary (Bertschek and 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

[26] 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).

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

proprietary (regime equation)[28]. Switching regression allows us to estimate the VC quality of OSS entrepreneurial ventures if the same ventures were in proprietary regime[29]. 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[30]. 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 of 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 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.

5. Conclusion and Discussion

In this paper, in an explorative fashion we investigate impact of OBM on the quality of VCs and the Governance of deals. This research is motivated by the fact that there are growing numbers of entrepreneurial ventures which are adopting OBM in order to support their innovation processes. These ventures are known by two distinctive features: of lack of reliance on IP and development in collaboration with agents outside firm boundaries (Mann, 2006). Research have shown entrepreneurial ventures by relying on communities of users are able to access to resources outside firm boundaries and generate high quality technology and products in lower cost (Lerner and Tirole, 2002; Chesbrough, 2003, 2006; von Hipple, 1988, 2005).

On the other hand, since entrepreneurial ventures cannot use traditional appropriability mechanisms to the fullest extent and should deal with agents, who do not have contractual ties to the entrepreneurial ventures, they are facing higher uncertainty and complexity in comparison with entrepreneurial ventures.

[28] 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.

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

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

We draw our conclusion based on a sample of 514 software entrepreneurial ventures that received VC funding in 6,555 different deals. Empirical analysis shows software entrepreneurial venture that that adopted OBM receive funding from higher quality VCs. The result can be driven from two different explanations. Firstly, VC's resource endowment and expertise help VCs to tolerate higher risk level and help to deal with business complexity. Secondly, high quality VCs are able to screen more efficiently and match with high quality entrepreneurial ventures (Hsu, 2004). We tested the second one by looking at successful exit (Merger and acquisition & IPO). The empirical analysis rolled out the second explanation since there are no differences in both variables between OSS and Proprietary entrepreneurial ventures.

In case of governance, results depict OSS entrepreneurial ventures on average receive VC funding in more rounds, but we did not find any significant differences in case of syndication size.

Staging more frequently allows VCs to monitor entrepreneur efforts and actions, reduce agency cost and reduce 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 increase likelihood of staging since value of the exit option is highly correlated with risk of investment (Li, 2008).

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 and Lerner, 1999) which is more severe for OSS entrepreneurial ventures which have a complex business model. As it was argued the speed to market has higher importance 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.

In this study contribute to two stream of literature. First, there are growing bodies of literature which have studied OBM, with special focus on OSS. The initial studies focused on understanding the motivation of contributors (e.g. Lerner and Tirole, 2002; von Hippel and von Krough, 2003; O'Mahony and Ferrero, 2007). By the growing number of firms that commercialize OSS software researchers investigate determinant of introducing open source products (Fosfuri et al, 2008; Wen et al, 2011), challenges and strategies for benefiting from open source communities (Dahlander and Magnusson, 2005; 2008; West and Gallagher, 2006; Bonaccorsi et al, 2006) and impact on performance of ventures (Piva et al, 2012; Stam, 2009). However, scholars have rarely explored the financing of firm involving in community collaboration (see Alexy & George, 2011, for an exception). Our study differs from Alexy and George (2011) in two distinctive features. First while, Alexy and George (2013) focus on adoption of OBM by publicly listed firms, we study entrepreneurial ventures, which are designed on delivering product and services based on OBM. Secondly, in contrary to Alexy

and George (2013) that explores the impact of OBM on the market value of firm, we focus on different dimensions of VC investment in OSS entrepreneurial ventures in comparison with proprietary ones. Finally, we contribute to this literature by offering unique data, to the best of our knowledge the most comprehensive, on OSS entrepreneurial ventures and by providing understanding on which type of VC and how they invest in OSS entrepreneurial ventures.

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 and 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), by focusing on product market strategy, show VCs are more willing to invest in innovator entrepreneurial ventures rather than 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. He finds prior founding experience, education in PhD level and social network of founder increases the likelihood of VC funding. 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 end with some thoughts about future research. We have been able to identify entrepreneurial ventures which collaborate with community of users. But it has been shown there is a large variance in business models of 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.

In this study we only focused on VC investment while future studies can study impact of VC investment on performance of OSS entrepreneurial ventures in comparison with proprietary one. The performance can be measured by several different proxies such as number of products, financial performance, exit and exit valuation. It would be also interesting to study OBM by looking at a different industry in which similar setting can be identified.

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Tables:

Table 1-Summary Statistics and Variable Definitions

	Dependent variables		N	Mean	Std. dev	Min	Max
	VC quality						
VC's general experience (1)	Number of investments in all industries prior funding date	VentureXpert	5465	328.67	547.91	0	6663
VC's industry specific experience (2)	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 (3)	number of rounds invested in entrepreneurial venture which went public	VentureXpert	5465	70.43	132.55	0	908
Capital under management (log) (4)	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 (5)	Between centrality in syndication network of preceding 5 years.		5465	0.53	1.23	0	11.09
	Governance						
Number of funding rounds (6)	The number of round entrepreneurial venture received VC funding	VentureXpert	1177	4.09	2.74	1	18
Syndication size (7)	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 (8)	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 (9)	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 (10), (11), (12), (13)	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 (21)	A dummy=1 if first round of VC funding is in seed or early stage	VentureXpert	6555	0.78	0.41	0	1
California (15)	A dummy variables indicating entrepreneurial venture is in California	VentureXpert	6555	0.47	0.50	0	1
Massachusetts (16)	A dummy variables indicating entrepreneurial venture is in Massachusetts	VentureXpert	6555	0.16	0.37	0	1
Sub-sector (17), (18)	Three dummy variables indicating whether entrepreneurial venture primary sub-sector is "Software Publishers" or "Software Reproducing" or "others".	VentureXpert					
Patents (19)	The cumulative number of patent application	EPO.org	6555	1.82	5.98	0	70

	prior to funding year						
	Deal Characteristics						
First round (20)	A dummy=1 if it is first round of VC funding	VentureXpert	6555	0.18	0.38	0	1
Company age (14)	Investment date- entrepreneurial venture founding year	VentureXpert	6555	4.07	2.98	0	21
	Macroeconomics conditions						
VC market size (22)	Logarithmic number of VC deals in time of funding	VentureXpert	6555	10.12	0.38	8.76	10.72
S&P index (23)	The rerun on S&P 500 index	Standard & Poor	6555	0.14	0.19	-0.37	0.37
Bubble (24)	A dummy=1 if year of funding is 1999-2000		6555	0.32	0.47	0	1
Crisis (25)	A dummy=1 if year of funding is 2007-2009		6555	0.23	0.42	0	1

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

Variable	N	Mean	Median	Test of equality (P-Value)	
				Mean	Median
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 3- Pair wise Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
(1)	1.00																								
(2)	-0.13	1.00																							
(3)	0.84	-0.11	1.00																						
(4)	0.42	0.08	0.39	1.00																					
(5)	0.55	-0.05	0.57	0.29	1.00																				
(6)	0.05	0.03	-0.01	0.10	-0.02	1.00																			
(7)	-0.04	0.03	-0.02	-0.03	0.02	0.03	1.00																		
(8)	0.11	0.13	0.09	0.12	0.05	0.12	-0.02	1.00																	
(9)	0.14	-0.02	0.15	0.16	0.00	-0.12	-0.25	-0.01	1.00																
(10)	0.01	0.04	0.04	0.12	-0.21	0.02	-0.13	-0.03	0.14	1.00															
(11)	-0.10	0.15	-0.12	-0.13	0.14	-0.01	0.11	0.04	-0.13	-0.63	1.00														
(12)	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)	-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)	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)	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)	-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)	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)	-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)	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)	-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)	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)	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)	-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	1.00		
(24)	-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	0.21	1.00	
(25)	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	-0.32	-0.31	1.00

Table 4- VC quality regression

	General experience	Industry Specific experience(%)	IPO experience	Capital under management(log)	Normalized Betweeness Centrality(%)
	(OLS)	(Tobit)	(OLS)	(OLS)	(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 5. VC Governance 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.

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 governance 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 $\beta_{ij}^{'}$ and $\beta_j^{'}$ 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.

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

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:

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

Where we have:

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

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

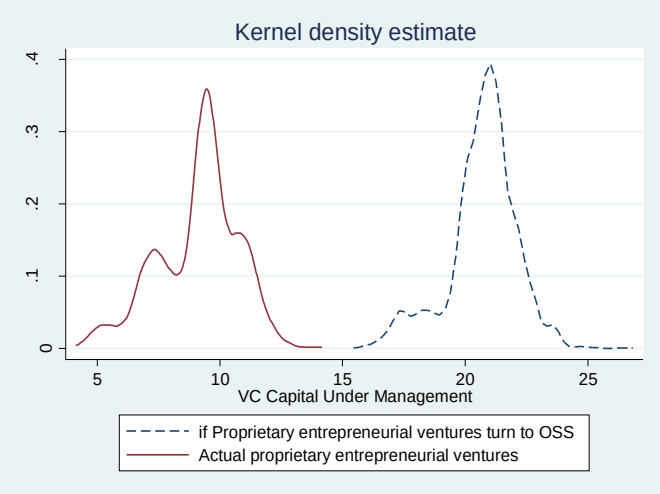
$$E(\varepsilon ij \mid OSSj, zi) = \sigma j \varepsilon \lambda i(zi\pi) \quad (5)$$

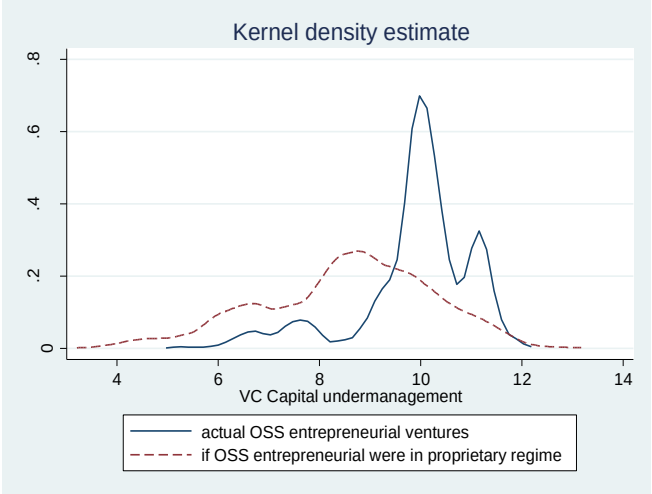
Where

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

$\lambda_i(z_i\pi)$ 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).

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

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

And in proprietary regime is:

$y_{i0=} \delta_{i0} x_j + \varepsilon_{i0}$ if OSSj= 0 (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:

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

Where $vi = a(\varepsilon i1 - \varepsilon i2) + ui$, 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):

$$L = \sum_i \left(OSSj \left\{ \ln\left(\Phi(\psi 1i) + \ln\left(\frac{\phi\left(\frac{\varepsilon 1}{\sigma 1}\right)}{\sigma 1}\right)\right\} + (1 - OSSj)\left\{ \ln\left(1 - \Phi(\psi 0i) + \ln\left(\frac{\phi\left(\frac{\varepsilon 0}{\sigma 0}\right)}{\sigma 0}\right)\right\}\right) \right. \quad (6)$$

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):

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

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

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

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