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## Venture capital investment, intellectual property rights protection and firm innovation: evidence from China

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#### ABSTRACT

We examine the heterogeneous effects of venture capital (VC) investment on firm innovation. Using a panel dataset of Chinese manufacturing firms, we find that VC-backed firms outperform non-VC-backed ones in patenting activities, new product sales, and exports because of the ex-ante selection and ex-post value-added effects of VC investment. Firms with better performance in innovation are more likely to get VC support, and such outperformance is magnified after the VC investment is made. Moreover, the impact of VC investment on firm innovation is greater when the protection of IPR is stronger. In addition, firms backed by more experienced VC firms (VCFs) generate more commercialized innovation but are less productive in patenting activities than firms backed by less experienced VCFs. Finally, firms backed by state-owned VCFs outperform in patenting activities but underperform in commercialized innovation those backed by other types of VCFs. Identification and selection issues are addressed by the propensity score matching approach and twostage estimations.

#### **ARTICLE HISTORY**

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#### **KEYWORDS**

Venture capital; innovation; intellectual property rights protection; VCFs' characteristics

## 1. Introduction

In a free market, firms may underinvest in R&D activities because the social returns to R&D are greater than their private returns (Nelson 1959). Venture capital (VC) investment is considered as one of the most effective financial instruments for financing innovative firms, especially young ones, which have difficulty obtaining other types of external financing (Kortum and Lerner 2000). Studies suggest that venture capital firms (VCFs) provide capital, exert intensive monitoring efforts and provide value-added support to their portfolio companies, mitigating investment risks and filling the market niche left by traditional financial institutions (Sahlman 1990; Gompers and Lerner 2001). Since the 1980s, many countries have initiated priority policies to promote the VC industry, expecting to stimulate corporate innovation (Brander, Egan, and Hellmann 2010).

Empirical studies on the relationship between VC investment and firm innovation are ample, but the findings are heterogenous. For example, some studies find that VC investment has significantly positive effects on firm innovation (Hellmann and Puri 2000; Mann and Sager 2007; Lockett et al. 2008), while others find no statistical relationship between the two (Bottazzi and Da Rin 2002; Engel and Keilbach 2007; Hirukawa and Ueda 2011; Arvanitis and Stucki 2014; Lahr and Mina 2016). Such results suggest that the impact of VC investment on firm innovation may depend on different factors and through different mechanisms.

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Despite the large body of empirical research on the relationship between VC investment and firm innovation, some knowledge gaps have not been adequately studied. First, we know very little about the factors that influence the impact of VC investment on firm innovation (Bertoni, Croce, and DAdda 2010). The answer to this question is crucial because only a better understanding of this issue will bring us closer to explaining why existing empirical studies have reached different conclusions about the relationship between VC investment and firm innovation. Second, the existing literature either uses patenting behavior or R&D investment, or new product sales or export output to measure firm innovation. However, none of it examines how VC investment affects different types of firm innovation in different contexts at the same time. For entrepreneurs and VCs, different goals and institutional contexts may influence their responses to different types of innovation. Thus, the impact of VC investment on different types of firm innovation is expected to be heterogeneous under different conditions. Third, existing studies rarely separate the selection effect from the treatment effect when examining the impact of VC on firm innovation. Research on this issue is important because only with answers to this question can we better understand the channels through which VC investment (if it does facilitate firm innovation) helps companies innovate.

This study attempts to fill the existing knowledge gap by adding evidence on how VC investment affects different types of firm innovation under different conditions based on firm-level data from China. Specifically, we focus on both technological innovation outputs measured by patenting activities (e.g. patent counts and patent citation counts) and commercialized innovation outputs measured by sales from new products and exports of small- and medium-sized enterprises (SMEs). We first ask whether VC-backed firms outperform non-VC-backed ones in the two types of innovation in China, and, if so, we disentangle whether such outperformance is caused by the ex-ante selection or ex-post value-added efforts by VCFs with rigorous research approaches. In addition, we examine how the impact of VC investment on different types of firm innovation is moderated by intellectual property rights (IPR) protection. Finally, we investigate how the characteristics of VCFs, including the ownership structure and experience, affect the impact of VC investment.

We are particularly interested in China for several reasons. First, China is currently the secondlargest VC market globally (Guo, Jiang, and Mai 2015). However, systematic analysis of this market is limited. More importantly, as a transitional economy, China's institutions are fundamentally different from those under a free market economy (Xu 2011). Therefore, an insightful understanding of this market may complement existing research on institutional factors influencing VC investment in different contexts. Finally, China is a vast country with significant cross-regional variations in economic development and institutional environments. Those variations allow us to examine how IPR protection influences VC effects in different regions within the same country, thereby controlling many country-specific effects that cannot be achieved in cross-country comparisons.

Based on a firm-level dataset ranging from 1998 and 2007, we find that VC-backed firms outperform non-VC ones in terms of both technological and commercialized innovation in China. In addition, we find that the outperformance of VC-backed firms in innovation is driven by both the exante project selection and ex-post monitoring efforts of VCFs. We use two methods, i.e. the Heckman two-stage least squares estimations (2SLS) with an instrumental variable (IV) and a difference in difference (DID) method, to address identification problems. Furthermore, we discover that the effects of VC investment are moderated by IPR protection and depend on VCF characteristics. Specifically, the impact of VC investment on firm innovation is further enhanced by stronger IPR protection. Moreover, government-owned/controlled VCFs (GVCFs) have greater impacts on firms' patenting activities but weaker impacts on firms' business innovation output than private VCFs (PVCFs) do. Finally, firms supported by more experienced VCFs generate greater commercialized innovation output while less technological innovation output than those supported by less experienced VCFs.

As the first systematic analysis on the impact of VC investment on the innovation of SMEs in China, this study enriches our understanding of VC investment in emerging markets and makes a general contribution to the literature in several ways. Above all, this study complements the existing literature on the relationship between institutions and VC investment. First, this study provides the first empirical analysis linking VC investment, corporate innovation, and IPR institutions at the firm level. Many studies have highlighted the importance of institutions for VC investment and various institutions are identified to affect the investment behaviors of VCFs and the performance of VCbacked firms (Black and Gilson 1998; Jeng and Wells 2000; Lerner and Schoar 2005; Kaplan and Strömberg 2003; Djankov et al. 2010; Bozkaya and Kerr 2014). However, surprisingly, how IPR institutions affect VC investment has attracted limited scrutiny (Ueda 2004). IPR institutions are critical to corporate R&D activities, as the extent to which innovations are legally protected determines the residual value that entrepreneurial firms can claim from (Griliches, Hall, and Pakes 1991). Therefore, it is expected that IPR institutions would affect the motivations and behaviors of VC investors and, hence, the impact of VC investment on firm innovation. As the first to provide evidence on how the effects of VC investment are sensitive to IPR protection, this study explores a new institutional dimension to explain the conditions under which VC affects firm innovation. Second, this study complements the existing studies on the impact of government engagement in VC investment by providing evidence from China, where the government has been deeply involved in business activities. The impact of government engagement has been a long-debating topic (Stiglitz 1988; Lerner 2009) and empirical studies have provided inconclusive evidence for the impact of GVCFs (Da Rin, Nicodano, and Sembenelli 2006; Cumming 2007; Brander, Egan, and Hellmann 2010; Bertoni and Tykvová 2015). The relationship between GVCFs and firm innovation in China remains understudied. Our study finds that in China, GVCFs have a greater impact on firms' patenting activities but a smaller impact on firms' commercialized innovation than other VCFs do. These results suggest that the impact of government participation in VC markets is heterogeneous, depending on the motivation and capacity of venture experts in different institutional contexts, and merit future research.

In addition, this study is among the first attempts to distinguish the ex-ante and ex-post effects of VC investment on firm innovation. Existing studies that separate treatment and selection effects mainly focus on firm growth or productivity (Bertoni, Croce, and DAdda 2010, Chemmanur, Krishnan, and Nandy 2011; Croce, Martí, and Murtinu 2013; Guo and Jiang 2013), and the findings are heterogeneous. Lahr and Mina (2016) is the only empirical work examining the impact of VC investment on firm innovation, differentiating the selection and treatment effects with rigorous approaches. The authors find evidence for the selection effects of VC investment on corporate patenting activity in the USA and UK. However, no treatment effects are discovered. This study complements while differs from Lahr and Minas (2016). By examining both the patenting activities and commercialized innovation, we find support for both selection and treatment effects of VC investment on both types of innovation output in China. Such results suggest that the channels through which VC investment affects firm innovation may differ under different institutional and financial environments, calling for further research on this subject.

Finally, this study complements but differs from existing research in that it examines VC effects on both the technological innovation (patent counts and patent citation) and the commercialization of the technological innovation (sales from new product and exports) and how different types of innovation are sensitive to IPR institutions and depend on the features of VCFs. Most existing studies focus on either the patenting activities (Mann and Sager 2007; Bertoni, Croce, and DAdda 2010) or the new product sales (Hellmann and Puri 2000) or export intensity (Lockett et al. 2008) of a firm. The heterogeneous effects of VC investment on different types of innovation attract little scrutiny. As Kortum and Lerner (2000) discussed, firms may spur patenting activities that do not impact innovation solely for impressing investors. If this is the case, investigating the patenting activities of entrepreneurial firms backed by VC investment alone may not tell how much contribution venture investment makes to innovation. This study shows that VC effects on different types of innovation vary under various IPR institutions and according to VCF characteristics.

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This paper is organized as follows. Section 2 reviews the literature and develops hypotheses. Section 3 describes the data and sample. Section 4 presents the findings on VCs' contributions to entrepreneurial firms' innovation, focusing on distinguishing the effects of ex-ante project screening and ex-post value-added efforts. Section 5 examines how the IPR institutions and the experience and ownerhship of VCFs influence the VC effects on firm innovation. Section 6 concludes the study.

## 2. Literature review and hypothesis development

In this section, we review the existing literature and discuss why we expect VC investment to be related to innovation outputs of entrepreneurial firms and how IPR institutions and the experience and ownership structure of VCFs are relevant in the Chinese context.

## 2.1 VC market in China and related studies

China is among the leading countries that have made numerous efforts to develop a vibrant VC industry and promote innovations. It has been the fastest-growing VC market in the past two decades. Currently, China is the second-largest VC market in the world. The annual disbursements of VC investment have increased from virtually zero in the 1980s to US\$5.6 billion in 2010 and reached US\$105 billion in 2018.<sup>1</sup> China share of the global VC market rose from 12% in 2010 to 38% in 2018. Meanwhile, VC investment plays an essential role in startups of high-tech firms in China, and VC-backed Chinese firms have become major contributors to the global initial public offering (IPO) market. By the end of the third quarter of 2018, China has 206 unicorn firms (203 in the USA), representing 41.7% of the globe total.<sup>2</sup> Moreover, more than 90% of Chinese unicorn firms are backed either by VC or other types of private equity investment.<sup>3</sup> In 2017 alone, 470 VC-backed Chinese firms went IPO in major stock markets globally (Zero2IPO, 2018), representing 30.9% of the total number of IPO cases and following-on offering deals globally in that year. These data suggest that the development of the Chinese VC market affects innovation in China and the world significantly.

However, concrete evidence is still lacking in the literature for knowing exactly how VC investments contribute (or do not contribute) to China innovation. This question is crucial for the following reasons. The number one reason is in practice, investment, and policymaking, given the size of the VC sector in China and the importance of sustainability of the Chinese economy to the world. The second reason is in academia. There have been intensive interests in the literature on the effectiveness of VC financing on innovation. Evidence, however, is mixed. One cannot take for granted believing or assuming that VC will work or should work in China as it does in some well-developed market economies. It is well documented that China suffers severely from many institutional problems that could impede VC and R&D in China. Among the examinations on VC investment in China, scholars mainly investigate the effects of VC investment on entrepreneurial firms' financial performance and growth (Guo and Jiang 2013; Jiang et al. 2014; Guo, Jiang, and Mai 2015). A few studies on the effects of VC investment on innovation are based on either province-level (Wen et al. 2018; Sun et al. 2019) or city-level data (Cheng et al. 2019). These studies mainly find positive effects of VC investment on a region innovation. However, many firm-level characteristics that may affect the influences of VC investment are not controlled without firm-level analysis. The only exception is the study of Jiang et al. (2019), which examines the post-IPO performance of VCbacked firms based on listed firms. Nevertheless, as it is well documented that only a small percentage of VC-backed firms have a chance to go IPO, an analysis on a sample focusing on only publicly listed firms may only capture successful VC-backed firms that may cause biases. How VC investment contributes to the innovation of SMEs in China still lacks scrutiny.

### 2.2 VC investment and firm innovation

The rationale which links VC investment and innovation lies in the fact that high-tech SMEs, usually financially constrained and having great growth potentials, can hardly access external funding because of the lack of collateral, severe information issues, and a high level of uncertainty. VCFs take high-risk-return profiles and fill in the market niche left by traditional financial institutions by playing an active role in selecting projects with growth potentials and putting great effort to monitor and support the firms they invest in (Gompers and Lerner 2001). In return, VC investment may enjoy high financial returns and promote innovation simultaneously.

Empirical studies find that the relationship between VC investment and innovation is heterogeneous. Primarily, studies find VCs indeed invest more in young and R&D-oriented companies in some countries (e.g. United States, Taiwan, and Israel) as they are expected (Elango et al. 1995; Gupta and Sapienza 1992; Avnimelech, Kenney, and Teubal 2004). However, in some other countries (e.g. Japan, Spain and Germany, among others), VCFs tend to support late staged privately held firms (Jeng and Wells 2000; Mayer, Schoors, and Yafeh 2005). Similarly, mixed results are found in terms of the relationship between VC investment and innovation outputs. Kortum and Lerner (2000) find that VC investment promotes innovation (measured by patents) based on US industry-level data. However, using similar US industry-level data, but with a longer time range, Hirukawa and Ueda (2011) find no relationship between patent counts and VC investment. At the firm level, some studies discover positive effects of VC investment on patent generation (Mann and Sager 2007; Bertoni, Croce, and DAdda 2010), marketing of new products (Hellmann and Puri 2000), and export intensity (Lockett et al. 2008) of entrepreneurial firms. Some other studies find no evidence to prove that VC investment is associated with firms' innovations (Bottazzi and Da Rin 2002; Engel and Keilbach 2007; Arvanitis and Stucki 2014; Mayer, Schoors, and Yafeh 2005). Moreover, Arqué-Castells (2012) discovers that the effects of VC investment on firm innovation appear to be an inverted U-shape over time in Spain. Most existing studies examine the relationship between VC investment and firm innovation without disentangling between the selection and treatment effects. To our knowledge, the study of Lahr and Mina (2016) is the only empirical work that examines the impact of VC investment on firm innovation, distinguishing between selection and treatment effects with a focus on firm patenting activities. This study finds that the positive relationship between VC investment and firm patenting activities is mainly caused by selection rather than ex-post effects. The authors suggest that such results may indicate that patents are used in VC investment primarily as a signal of commercially viable know-hows of entrepreneurial firms at the time of project selection.

We still lack a systematic and thorough understanding of the different results from the above empirical studies. However, the mixed results suggest that the impact of VC investment on firm innovation depends on various factors. Above all, the pre-condition for VC investment having positive effects on innovation is that high-tech SMEs, which can generate innovations, are financially constrained, and they may not invest in R&D activities unless they can access external funding from VCs. Investing and implementing R&D activities may involve various costs due to the handling of new resources or reallocation of existing firm resources (Lucas 1967). If a firm chooses to finance itself regardless of whether it gains VC investment or not, the adjustment costs of additional R&D investment will likely become too high. VC investment may exert limited effects on R&D investments or firm innovation in this situation. So, it is expected that the effects of VC investment on firm innovation depend on the severity of entrepreneurs' financial constraints and innovation motivations.

In addition, the capabilities and motivations of venture experts, market conditions and institutional environments may influence the effects of VC investment on different types of innovation. It is worth noting that VC, as a particular type of private equity instrument, is not designed to promote innovation but to provide high returns to investors in a market economy (Kortum and Lerner 2000). Therefore, VCFs should only strive to invest and support innovative projects if they foresee that the innovation will be commercialized and translated into a high return that offsets the risk. Thus, the more competent and incentivized the venture experts are, and the more the institutional environment encourages firms to commercialize their innovations, the more likely VCFs are to support and commit to innovations with high levels of uncertainty and information problems. On the other hand, however, the greater the uncertainty in the market is and the more severe the information problems are, the more likely VCFs are to select and support innovations with less uncertainty. The fact that VCFs invest more in early-stage high-tech companies and have a greater impact on firm innovation in the USA than in Europe generally supports the arguments about the incentives for firms to innovate, the competence and incentives of venture experts, and the information issues as well as institutional environments for innovation in different regions.

In China context, Chinese SMEs have suffered from a lack of access to external finance (Gordon and Li 2003; Allen, Qian, and Qian 2005; Guo, Guo, and Jiang 2022). For example, Guo et al. (2014) discovered that private enterprises' bank loan over equity ratios were 0.6% and 0.8% in 2006 and 2010, respectively. Furthermore, Chinese firms generally have higher proportions of short-term debt in their capital structures than firms in other countries (Li, Yue, and Zhao 2009). The lack of access to external financing resources and long-run debts suggests that firms in the private sector may face severe liquidity constraints for long-run investment in R&D activities. Therefore, VC investment is a critically important source of funding for high-tech SMEs to pursue innovation activities in China (Guo and Jiang 2013).

At the same time, there is a high degree of uncertainty and severe information problems associated with investing in innovative SMEs in China for a variety of reasons, including the weak IP institutions and law enforcement, the lack of corporate credit and business records, and the absence of standard accounting and auditing systems in this country (Allen, Qian, and Qian 2005; Guo, Guo, and Jiang 2016). With such uncertainty and information issues, we expect VCFs in China to choose and commit to firms with the innovation of lower risks and stronger commercialization potentials.

On the other hand, encouraging corporate innovation, especially patenting activities, has become a strategic national policy in China since the late 1980s. Various fiscal policies, including direct R&D subsidies, interest-free loans and tax breaks for innovative firms, have been designed to incentivize firms to invest in R&D activities.<sup>4</sup> Firms' patenting activities serve as one of the most important factors for gaining these policy supports (Guo, Guo, and Jiang 2016; Gong and Peng 2018). In China, obtaining government support brings not only direct economic benefits but also political capital that can generate a strong certificate effect, thus helping firms to obtain huge commercial benefits such as follow-up investments or bank loans or government procurement contracts (Guo, Guo, and Jiang 2022). Therefore, although the effects of these favorable policies on the commercialization of technologies are heterogeneous, the number of invention patents granted increased by 97-fold between 2000 and 2016 (Gong and Peng 2018). As a result, both venture experts and entrepreneurs see significant economic and political benefits from continuously generating technological innovations.

Combining the discussions on the factors affecting the impact of VC investment on firm innovation and the understanding in China contexts, we posit the following hypothesis:

Hypothesis 1a: VC-backed firms outperform non-VC-backed firms in technological and commercialized innovation output.

Hypothesis 1b (ex-ante selection effects of VC investment): More innovative firms are more likely to be selected by VCs.

Hypothesis1c (ex-post effects of VC investment): VC-backed firms generate magnified innovation output after receiving VC investment compared with non-VC-backed ones.

## 2.3 IPR protection, VC investment and firm innovation

The relationship between IPR protection, external financing and innovation is debated among scholars. In this subsection, we will first discuss the existing literature on this issue and then turn to an analysis of the Chinese context and our prediction regarding how IPR protection affects the impacts of VC on innovation in China.

On the one hand, IPR protection may positively affect investment in R&D activities and thereby the innovation outputs of the high-tech firms. First, the rationale for external financiers and entrepreneurs to invest in innovations is to seek the profit generated from the innovative products or services. However, it is known that innovations usually generate positive externalities that competitors may have a chance to free ride the intellectual properties of inventors (Nelson 1959). Therefore, investors and entrepreneurs may lack interest in investing in innovations when the imitation costs of competitors are low. In this case, strong protection of IPRs may increase the costs of imitation of competitors so that the investment returns from innovation can be increased (Griliches, Hall, and Pakes 1991). Second, as we have discussed, investment in R&D is associated with a high level of information asymmetries. Such information asymmetry may reduce the incentives of financiers to invest in R&D projects and thereby lead to underinvestment in innovation. This situation is particularly serious when IPRs are not well protected because entrepreneurs may hesitate to provide sufficient confidential information to investors if they expect that the financiers may have a chance to steal their innovative ideas (Ueda 2004). In such a case, strong IPR protection may help mitigate the information issues between financiers and entrepreneurs and thereby stimulate external finance in innovations.

On the other hand, IPR protection may be useless or negatively affect external investment in R&D activities and innovation outputs under certain circumstances. Several recent studies argue that some innovations are sequential and complementary so that an inventor payoff may be enhanced by imitation and competition (Scotchmer and Green 1990; Bessen and Maskin 2009). Specifically, these studies suggest that imitation of these innovations can be socially and privately desirable. Imitators may have better ideas to enhance the original inventor innovations, thereby pushing the pace of overall innovation of a sector. Moreover, with inspirations from various imitators, the original inventor may generate more innovations and the future profits from the follow-up innovations may offset the reduced profits caused by imitations. However, as Bessen and Maskin (2009) emphasized, there are two pre-conditions for imitations of sequential innovations to be desirable for inventors, i.e. the entry cost for imitators is not zero and it takes time for imitators to enter so that the inventors can enjoy the returns from the original innovations at least temporarily. In such a case, IPR protection may not help stimulate innovations. Indeed, the empirical analysis presents a mixed picture. Some empirical studies find IPR institutions positively affect innovation (Mansfield, Schwartz, and Wagner 1981; Ang, Cheng, and Wu 2014; Fang, Lerner, and Wu 2017) and technology transfer (Gallini 2002; Branstetter 2006). Some others discover an insignificant or negative relationship between IPR institutions and innovation (Branstetter and Sakakibara 2002; Qian 2007).

As far as China is concerned, IPR protection is still a new concept. IPRs were not legally protected until the 1980s, when China became a member of the main international conventions to protect intellectual property rights. Since then, a comprehensive legal framework for protecting trademarks, copyrights and patents has been established by drawing on international standards. Meanwhile, a series of policies and laws focused on strengthening IPR protection has been enacted since 2000. Examples of such policies include *The Opinions on Strengthening the Protection and Management of Intellectual Property Rights Related to Science and Technology of China* promulgated in 2000, and the revised *Science and Technology Progress*, which took effect in 2007. In addition, as discussed previously, China has been very active in encouraging corporate innovation by offering various incentives to companies that apply for patents. As a result, by the end of 2018, China had granted more than 1.6 million patents for inventions, with 432,000 granted in 2018 alone.

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Although legislation for IPR protection is progressing well and patent applications are growing rapidly, it is well documented that enforcement of IPR laws is weak and IPR violations are common in China (Wang 2004). In 2018, more than 35% of members of the American Chamber of Commerce in China suggested that weak IPR protection is a severe impediment to their R&D investments in this country. <sup>5</sup> In addition, studies discover that IPR enforcement varies significantly across regions in China. For example, Ang, Cheng, and Wu (2014) find that plaintiffs' success rates in IPR infringement cases range from 25% to 87.5% across Chinese provinces. Similarly, Fang, Lerner, and Wu (2017) find that the length, cost, and fairness of resolution vary significantly across regions in China. This cross-regional variation in IPR enforcement in China is understandable. As Xu (2011) discussed, local authorities have significant power in almost every aspect of local governance under the authoritarian system of regional decentralization, including enforcement and implementation of central government policies. The cross-regional differences in IPR institutions provide an excellent opportunity to estimate, using a quasi-experimental approach, how the impact of VC on firm innovation is sensitive to IPR protection.

Based on the literature mentioned above and the understanding of IPR protection in China, we argue that the effects of VC investment on firm innovation are positively moderated by IPR protection. On the one hand, the potential risk of IPR infringement is high due to weak IP law enforcement and the low cost of patent imitation in China. On the other hand, suppose technology-oriented firms backed by VC investment are in a region with relatively weak IPR protection. In that case, competitors can easily exploit the benefits of innovation and entrepreneurs may not be willing to share confidential information of their technologies with potential investors, which may discourage external investment in R&D activities and reduce external investment in R&D-intensive firms. As a result, the marginal returns from strong IPR protection are high. On the other hand, it is well documented that Chinese firms lack breakthrough innovations and many firms apply imitation strategy in innovation (Luo, Sun, and Wang 2011). In addition, Chinese companies are known for their ability to quickly emulate the latest technologies through reverse engineering and advanced manufacturing facilities (Luo, Sun, and Wang 2011). At the same time, studies find that imitations, especially creative imitations, may bring about significantly high financial performance in China (Lee and Zhou 2012). As such, the benefits of relaxing IPR protection for sequential and complementary innovation may not apply in China, given that the entry costs for imitators are relatively low and the imitation lead time is short. Hence, inventors may not enjoy the first-mover advantage sufficiently before the imitators share the innovation returns. Therefore, we suggest that in China context, strong IPR protection is vital for external financiers to invest in and support innovations of SMEs and therefore magnify the VC investment effects on the entrepreneurial firms' innovation outputs, including the technological and commercialized ones. We posit the following hypothesis:

Hypothesis 2: The positive effects of VC investment on both types of firm innovation are magnified when the IPR protection is stronger.

## 2.4 VC investment, characteristics of VCFs and firm innovation

The characteristics of VCFs may affect the impacts of VC investment on firm innovation. In this study, we focus on two major aspects, i.e. the experience and ownership of VCFs.

Above all, VCFs' experience and reputation are suggested to be critically important to determine the investment effects. As we have discussed earlier, innovation is a complex process associated with profound information problems, and it is well documented that investing in innovation is highly risky. The experience of VCFs may determine whether the project screening and monitoring strategies can be implemented well and, therefore, reduce the investment risk. Indeed, Hsu (2004) finds that reputable VCFs may invest in entrepreneurial firms at discounted prices. Petkova et al. (2014) discover that more reputable VCFs invest more in the emerging sector and employ more riskreduction strategies. Meanwhile, Nahata (2008), Krishnan et al. (2011), and Guo, Jiang, and Mai (2015) find that companies backed by more reputable VCFs or VCFs with more experiences are more likely to have better performance at and after IPOs. Furthermore, Atanasov, Ivanov, and Litvak (2012) discover that reputation limits opportunistic behaviors of VCFs towards entrepreneurs.

Although studies have linked the experience of VCFs and entrepreneurial firms' performance, most of them are focused on the financial returns or corporate governance rather than the firms' innovation outputs. For career and reputation concerns, a manager normally hesitates to engage in risky R&D activities because if such projects fail, it is difficult to distinguish whether the outcome is caused by a purely technological failure or by moral hazard issues of the manager. Entrepreneurs' reputation is even more important than that of managers in established companies because startups often require more than one round of investment and many entrepreneurs are serial entrepreneurs. Damage to reputation will lead to significant losses. Therefore, research suggests that increased monitoring from capable institutional investors can provide firms with more incentive to innovate because this insulates managers from the reputational concerns of failure (Aghion, Van Reenen, and Zingales 2013).

In China context, information issues are even more severe than those in developed counties, given the lack of credit record systems and weak law enforcement. Therefore, we would expect that the investment professionals' capability to monitor and support entrepreneurial firms is critically essential in VC investment. Indeed, Guo and Jiang (2013) and Guo, Jiang, and Mai (2015) find that VCs' efforts and experience affect entrepreneurial firms' financial performance in the long run. As for innovation incentives, we expect entrepreneurs in China to be even more unwilling to undertake R&D activities with high risks than their counterparts in western countries because of the more severe information issues. Therefore, the experience of VCFs should be potent in determining the R&D decisions and innovation outputs of entrepreneurial firms in this country. Moreover, the experience of VCFs may affect different types of innovations in different ways. More experienced VCFs may have greater ability and motivation to identify a technology commercialization potential and, therefore, have a greater positive impact on commercialized innovation than less experienced VCFs. On the other hand, lacking the ability to judge the commercialization potential and thus have a greater influence on a firm patenting activities. We posit the following hypothesis:

Hypothesis 3a: Firms backed VCFs with more investment experience outperform those backed by VCFs with less investment experience in commercialized innovation.

Hypothesis 3b: Firms backed VCFs with less investment experience outperform those backed by VCFs with more investment experience in patenting activities.

At the same time, the ownership of VCFs may affect the objectives and governance of VCFs and therefore affect the impact of VC investment. In this study, we focus on comparing GVCFs and their private counterparts. Governments in many countries worldwide promote VC investment (Brander, Egan, and Hellmann 2010). One of the main approaches, especially in Europe and some emerging markets, is the direct creation of GVCFs, with the aim that these state-owned or controlled VCFs can fill the market gap left by PVCFs by supporting high-tech companies with higher levels of uncertainty and more severe information problems. It has been a long-term debate regarding whether government interventions can be a real solution to the market failure of underinvestment in R&D by for-profit firms. Governments may fail due to rent-seeking issues and bureaucratic inefficiencies, and thereby the public intervention may crowd out private R&D investments (Stiglitz 1988; Lerner 2009).

Empirical studies provide inconclusive evidence for the impact of GVCFs. At the aggregate level, some studies find GVCFs complement the PVCFs (Cumming 2007, 2011), while some find GVCFs crowd out private funds (Cumming and MacIntosh 2006; Da Rin, Nicodano, and Sembenelli 2006). Estimations based on firm-level data emerged more recently and similarly, mixed findings are

discovered. For instance, a few studies find that GVCFs select promising firms to help them access further external investment (Guerini and Quas 2016) or increase the valuation of these firms (Colombo et al., 2016). Some other studies find that GVCFs have limited effects on the growth (Grilli and Murtinu 2014) and patenting activities (Bertoni and Tykvová 2015) of their portfolio companies in Europe. Moreover, several studies find that GVCFs negatively affect firm productivity (Alperovych, Hübner, and Lobet 2015) or patenting activities (Brander, Egan, and Hellmann 2010).

The relationship between GVCFs and firm innovation in China remains understudied. In China, as in many other countries around the world, GVCFs have specific political and social objectives: to support young high-tech companies and stimulate corporate innovation, which can bring positive externalities to society (Suchard, Humphery-Jenner, and Cao 2021). Above all, we expect that both GVCFs and PVCFs positively affect firm innovation because of the severe financial constraints faced by entrepreneurs and the strong public policy to encourage firm innovation, as we have discussed earlier. However, the two types of VCFs may have different effects on the commercialized innovation and patenting activities of their portfolio companies.

Compared to PVCFs, GVCFs may have a stronger positive impact on firms' patenting activity. As we have discussed earlier, encouraging corporate innovation is one of the primary goals for establishing GVCFs. Moreover, patents have been regarded as one of the most critical measures for firm innovation in the past years (Gong and Peng 2018). How well the portfolio companies do in patenting serves as an essential performance measurement for GVCFs (Guo 2010). Moreover, venture capitalists of GVCFs may be less capable and have lower incentives to take high-level risks and identify the commercialization potentials due to SOEs' lower-powered incentive schemes and bureaucratic organizational structure (Xu 2011; Guo et al. 2021). Thus, both political pressure and the organizational nature of GVCFs dictate that GVCFs may be inclined to invest and provide more effort to help firms with more active patenting activities because patents are more visible, easier to measure and verify, and more likely to be recognized by the higher authorities of GVCFs. As a contrast, as we have discussed earlier, PVCFs may only commit to technology when they see the commercialized innovation of their portfolio firms. We hence posit the following hypothesis:

Hypothesis 3c: Firms backed by GVCFs outperform those backed by PVCFs in technological innovation measured by patenting activities.

Hypothesis 3d: Firms backed by PVCFs outperform those backed by GVCFs in commercialized innovation.

## 3. Data and samples

## 3.1 Data sources

The data in this study mainly come from four sources, namely, Above-scale Industrial Firms Panel 1998–2007 (ASIFP), VentureXpert, State Intellectual Property Office (SIPO), and European Patent Office (EPO). First, firm-level data on financial information, sales from new products, exports, and other firm-specific characteristics are obtained from ASIFP, published annually by the National Bureau of Statistics of China from 1998 until 2007.<sup>6</sup> This database consists of virtually all state-owned manufacturing firms and non-SOEs with annual sales of at least RMB 5 million. One limitation of ASIFP is that it does not include non-state firms with less than RMB 5 million sales. One potential concern with such limitation is that VCs are interested in small and medium-sized enterprises (SMEs); estimations based on the ASIFP dataset may cause biases if such SMEs are missed in the data. To estimate whether the limitation of ASIFP may cause severe biases for our estimations, we compare the data in ASIFP 2004 with those in the Chinese Economic Census conducted in 2004. The

comparison shows that the enterprises covered by this database account for 90% of the total sales of all industrial firms in China.<sup>7</sup> For the period 1998–2007, approximately 84% of the firms in the sample were small or micro-enterprises according to the standard released by the Chinese government; thus, most of the firms covered in the ASIFP database are SMEs.<sup>8</sup> Another limitation of the ASIFP database is that it only covers manufacturing firms. However, VC investment is concentrated on the service sector such as software, AI, online commerce and entertainment, and the Internet of Things. So, our analysis will not capture the innovation of those companies, which calls for concerns of lack of representativeness. However, we also realize the limitations of the current academic analysis in measuring innovation outputs for the service sector (e.g. new products sales, patents and patent citations, etc.); instead, they are embedded in trade secrets, process innovation or business model innovations that can hardly be accessed. The advantage of using ASIFP data is that we may have more observable and more accessible measurements for innovation for manufacturing firms.

Second, the investment information for VC-backed firms comes from VentureXpert. For each VCbacked firm, the dataset includes the name, location, industry (in four digits) of the firm, the total amount of venture investment gained by the firm, the number of VCFs involved in each deal, and the number of venture financing rounds for each firm. In addition, for each VCF, the dataset provides information on its age, location, and the number of funds under management.

Third, patent data are obtained from the SIPO and EPO. The SIPO database provides complete information on all patents granted in China, including the application and publication number of the patent, application and grant year, IPC classification number, type of the patent, and assignee of the patent. EPO provides information on the citation of patents across the world.

#### 3.2 Data matching and samples

The first challenge of this study is data matching because we utilize data from various sources, and the names of the firms listed in the four databases may not be entirely consistent. First, we need to match the list of VC-backed firms in the VentureXpert with the list in the ASIFP database to identify which firms in the ASIFP database have won VC investment and obtain detailed financial information for these firms. We also need to match the firms in the ASIFP database with those in SIPO and EPO patent databases to identify patent information for all firms in the estimations. We generally borrow data matching strategies used by the NBER Patent Data Project<sup>9</sup> (NBER Project) to ensure matching accuracy.

Overall, our basic sample contains two parts: VC-backed firms and randomly matched non-VCbacked firms. We first match the data from VentureXpert and ASIFP to obtain detailed financial information for VC-backed firms for each year. As the first step, we extract a list of 2,527 VC-backed firms that received their first VC investment before January 2011 from the VentureXpert database. The firm names listed in VentuerXpert are in English; thus, we first confirm their Chinese names through websites and other online sources. As a result, we obtain the Chinese names of 2,518 firms. Next, we standardize firm names in both databases and create a 'standard name' for each firm in the two databases by removing the punctuations, spaces, or other special characters (e.g.  $\%^{\&-} = [/]$ , etc.) and by standardizing the legal entity identifiers (e.g. we converted Limited into Ltd.), using similar algorithms used by NBER Project. We then created a 'stem name' for all firms by removing all legal entity identifiers in firm names (e.g. a firm called 'Long Cheng Logistics Ltd' is changed to 'Long Cheng Logistics'). Afterward, we match the Venturexpert data with ASIFP data by the standard names, locations (at city level), and the industries of firms using computerized matching to generate a matched file called 'full matching'. Subsequently, we match VC-backed firms with the ASIFP database using 'stem names', locations (at city level), and industries of the firms to generate a matched file called 'partial matching'.<sup>10</sup> We then combine the matching results of the two matching approaches and delete duplicates by using identical legal person codes of each firm by year. After computerized matching, we cross-check the matching results manually to ensure accuracy using Google and Baidu search engines.

After the matching mentioned above, we identify 847 VC-backed firms covered by ASIFP, which obtained their first round of VC investment before 2011. The sharp decrease in the number of firms reflects the presence of numerous VC-backed firms in the Internet service or software-related industries, which are not included in ASIFP. We then further trim the sample by excluding firms that received their first round of VC investments after 2007, leaving a sample of 311 firms. The reason is that ASIFP data is only available between 1998 and 2007. So, for those firms which obtained their first round of VC investment. As our estimates focus on the difference-in-difference comparison for the innovation outputs for firms before and after gaining the VC investment, losing the firm-level information for the ex-post VC investment period would not allow us to apply the DiD estimates. We therefore have to exclude those observations. We also need to exclude VC-backed firms for which ASIFP does not have financial information for the DiD matching. So, eventually, 268 VC-backed firms covered by ASIFP are left for our estimations. The final sample represents approximately 50% of all manufacturing firms in China that received venture investment between 1998 and 2007.<sup>11</sup>

Additionally, to examine the effects of VC investment, we need to construct a control group of firms that did not receive VC (i.e. non-VC-backed firms). To define this control group, for each VC-backed firm, we select all potentially matchable non-VC-backed firms from ASIFP to first construct a potential matching sample through a pre-filtering with the following characteristics: same industry (at the two-digit SIC level), same location (at the provincial level), similar firm age (the difference in terms of firm age between VC-backed and non-VC-backed firms is not larger than one year), and similar firm size (the difference in terms of the total number of employees is not larger than 10% of VC-backed firms' size) at the time of VC investment, following the existing studies (Croce, Martí, and Murtinu 2013; Grilli and Murtinu 2014; Colombo and Murtinu 2017; Cumming, Grilli, and Murtinu 2017; Murtinu 2021). Then, for each VC-backed firm, we randomly draw one-to-five matched pairs to build the control group from the potential matching sample of a non-VC-backed firm sample. To ensure that our control group is representative, we repeat this random drawing methodology 15 times. The results have remained consistent.

Table 1 presents the industry distribution of the sampled VC-backed firms at the two-digit SIC level. VC-backed firms are concentrated in high-tech industries, such as those that produce telecommunication and computer products, electronic and electrical equipment, chemical products, pharmaceutical products, machinery and equipment products, and instrument-related products. Firms in these industries comprise about 60% of the VC-backed firms sampled. This figure is consistent with the industry distribution of VC-backed firms reported by Zero2IPO 2001-2009). The distribution of the sampled VC-backed firms suggests that our sample fairly represents the entire sample of VC-backed firms.

After identifying VC-backed firms and their non-VC-backed counterparts from ASIFP, we obtain the information on patents and patent citations for each firm in the sample. SIPO database and EPO database offer firm-level patent information. In particular, SIPO provides all patents granted to firms

Industry	2-digit SIC	# Of Firms	Percentage
Motor Vehicles and Parts	36	11	4.1
Special Equipments	35	17	6.34
Medical Products	27	23	8.58
Computers, Communication and Other Electronic Products	39	27	10.07
Chemical Material and Chemical Products	26	31	11.57
Meter and Related Devices	40	49	18.28
Other industries		110	41.06
Total		268	100

 Table 1. Distribution of VC-backed firms by industry.

This table presents the industry distribution of the VC-backed companies in our sample. Industries are presented in 2-digit standard industry codes (2-digit SIC). We report the total number of firms in an industry (# of Firms) and the percentage of firms of an industry in the total sample (Percent).

in China since 1985, whereas EPO provides information on the citation of the patents across the world. We first match the data of SIPO and ASIFP to gain information for patents for each firm. The matching between SIPO and ASIFP is similar to that between VentureXpert and ASIFP. After matching, patent information from SIPO, such as the publication number of a patent, is attached to the firms in ASIFP. We then match EPO data with ASIFP using the publication number of the patents, which is identical for each patent listed in the two patent databases. By doing so, we gain patent information for both VC-backed firms and their non-VC-backed counterparts. Given that creating patentable works and applying for a patent take time, we use the filing time of newly granted patents as a basis in panel estimations. We also use the one-year lag of filing time for all estimations to check the robustness of the results.

A potential concern with patent matching is the miscounting patents generated by firms' subsidiaries. According to the Patent Law of China, organizational patent applicants must provide the registration license while applying to file a patent, suggesting that a firm that applies for patents must be an independent legal entity. Patents applied by subsidiaries that are not registered as independent legal entities will be filed to the parent firms. Similarly, only an independent legal entity will be recognized as an individual firm. Therefore, based on the names and locations of firms (for cross-sectional data matching by year) and legal person codes (for panel construction), our matching approach should not be affected by miscounts for firm subsidiaries.

#### 3.2 Variables

The innovation of firms is our primary interest in this study. We examine two aspects of innovation, namely, the technological innovation outputs and the commercialized innovation outputs. We measure technological innovation outputs by the number of newly granted patents of the firm in a given year (*Patent*) and the increase in the number of patent citations of the firm in a given year (*Citation*) as derived from SIPO and EPO, respectively. Commercialized innovation outputs are measured by the increase in sales from new products (*Dif\_New\_Prdct*) and the increase in exports (*Dif\_Exports*) of the firm in a given year.

We are interested in the effects of VC investment on the innovation of entrepreneurial firms within the examination period. Hence, we need a variable to distinguish whether VCs back the firm or not. First, the **VC\_Dummy** variable equals one if the firm is backed by VCs and zero if otherwise. A significantly positive coefficient on this variable implies that VC-backed firms generally have stronger innovation outputs. Second, the **VC\_Entry** dummy variable divides the entire examination period into two parts: before and after venture investment. **VC\_Entry** is equaled zero for the period before the investment is made and one for the period after the investment is made. The value of this variable for the firms in the control group is determined by their pairs in the VC-backed group. We use this variable to test the structural change effect before and after the infusion of VC investment. Finally, we include **VC\_Post**, an interaction term of **VC\_Dummy** and **VC\_Entry**, in our regression to test whether the innovation change after the VC investment infused is the same for VC-backed and non-VC-backed firms.

We use three variables to capture the level of IPR protection across regions. The first two variables focus on the severity of patent infringement in a region. Patent infringement is not without cost. An infringer will only infringe a patent if he/she expects the penalties for an infringing activity to be lower than the benefits. According to Chinese law, lawsuits on IPRs need to be raised in local courts where the infringement occurs. In regions with stronger IPR protection, the infringement cost should be higher than that in other regions, so the patent infringements reflect the lack of proactive and deterrent IPR enforcement in China, especially locally (Stratford 2006; Du, Lu, and Tao 2008). The first variable for IPR protection is the ratio of the total number of patent infringement cases filed over the total number of patents granted in a province each year (denoted as *Infringement Filed*). The second variable is the ratio of the total number of patent infringement cases closed over the total

number of patents granted in a province each year (denoted as *Infringement Closed*). The lower the two ratios are in a region, the stronger the IPR protection is. The third measurement for IPR protection, as an alternative one, is the IPR index (denoted as *IPR\_Index*) obtained from China Marketization Index (CMI, 1998–2007). The CMI is a set of indices published annually since 1997 to date, constructed based on data from various sources at the provincial level (Fan, Ma, and Wang 2019). One sub-index is the index measuring IPR protection, a weighted score calculated based on the total number of patents filed and granted per R&D professional in a province each year. We understand that this is not an ideal measurement for IPR protection because the number of patents can be driven by other factors. However, there is no doubt that the local IPR law enforcement is essential for patenting activities. We use such a variable to conduct some supplementary estimations for robustness checks. The higher the value of this variable is, the better IPR protection is in that region.

We are also interested in how the different types of VCFs add value to their portfolio firms, which necessitates analyzing the investment experience and ownership of the VCFs. VCFs typically syndicate investment, and the lead VCF is intensively involved in the governance of portfolio companies. Hence, we use the information of the lead VCF to measure the experience and ownership of VCFs. Based on literature (Lee and Wahal 2004; Nahata 2008), we define the lead VCF as the firm that makes the largest total investment across all rounds of funding in an entrepreneurial firm. The information for measuring the characteristics of VCFs is obtained from the VentureXpert database.

We measure the experience of a VCF in two ways; namely, the age of a VCF and the total number of VC deals a VCF has closed at the time of investing in a specific entrepreneurial firm. The first set of measurements is constructed according to the age of the lead VCF at the time of making the investment. VCFs need to continuously raise new venture funds based on their reputation to survive in the VC market. Therefore, the longer a VCF exists, the greater the number and the larger amount of VC funds it manages, and the more investment deals it closes (Gompers 1996; Lee and Wahal 2004; Gompers and Lerner 1999). On average, the life span of a VC fund is seven to ten years (Gompers and Lerner 1999). However, according to the Yearbook of the National Venture Capital Association), most of VCFs seek an extension of fund management. The average time to liquidation for VC funds is between 12 to 14 years, with 46% of VCFs taking 15 years or even more to liguidate. VCFs younger than ten years old usually do not liquidate their first VC funds under management and cannot demonstrate their performance to the market, making it difficult to raise many next rounds of fundraising. Therefore, these VCFs should have substantially less investment experience than those which have survived the first ten years and should have secured the next rounds of funding raising. We therefore take ten years as a cut-off for VCF age as a proxy for the experience of a VCF. Dummy variable VCF\_Age1 is equal to one if the lead VCF is younger than ten years when the VCbacked firm gained its first VC investment. Otherwise, it is equal to zero. Dummy variable VCF\_Age2 is equal to one if the lead VCF is older than ten years when the VC-backed firm gained its first VC investment. Otherwise, it is equal to zero.

The second set of measurements for VCFs' experience is the total number of deals closed by the VCFs when investing in a given firm. As discussed, the larger the number of deals a VCF closes, the more experience it has accumulated. Specifically, we employ 100 deals as a cutoff for this measurement. Among the 268 VC-backed firms covered by our sample, 141 firms' lead VCFs (52.6%) have closed 100 or more venture deals by the time of the investment, while 127 firms' lead VCFs (47.39%) have closed fewer than 100 venture deals by the time of the investment. Dummy variable **VCF\_Comp1** is equal to 1 if the lead VCF has closed fewer than 100 venture deals by the time the investment in a given entrepreneurial firm has been concluded and 0 if otherwise. Likewise, dummy variable **VCF\_Comp2** is equal to 1 if the lead VCF has closed 100 or more venture deals by the time the investment in a given entrepreneurial firm has been concluded. Otherwise, it is equal to 0.

For the ownership of VCFs, we took the names of the lead VCFs from the Venturexpert database and then browsed the websites of every lead VCF to collect the ownership information. Although Venturexpert provides the ownership information for VC funds, i.e. whether a VC fund under the management of a VCF belongs to a government program, it does not provide the ownership information for the VCF. So, we hand collected such data to ensure the accuracy of the estimations. *GVCF* is a dummy variable that equals one if more than 50% of the VCF is owned by the state and zero if otherwise. *PVCF* is also a dummy variable that equals one if the state owns less than 50% of the VCF and zero if otherwise.

Four control variables, namely, age, size, leverage ratio, and the percentage of state shares of the firm, are included in the analysis. ASIFP provides information on the founding date of firms. We use this information to calculate the *Firm Age. Firm size* is measured by the total number of employees in a natural logarithm format. We also include the leverage ratio in the estimates. VC investment does not require collateral. However, investing in entrepreneurial firms is associated with severe information and uncertainty issues. Hence, VCs may consider the liquidation value of firms when making investment decisions, inducing them to select firms with low leverage ratios. *Leverage* is the total liability divided by the total assets of a firm.

Additionally, we control the ownership structure of the firm. Major institutional shareholders would affect the extent to which VCs may influence decision-making in their portfolio companies. VCs may prefer firms with fewer state shares because the non-profit-oriented interests of state owners may conflict with their interests. Additionally, state ownership may affect VC governance after the investment is made. *State Ownership* is the ratio of state-owned stake divided by the firm total equity.

#### 3.4 Summary statistics

Table 2 provides the summary statistics of VC-backed firms, including means, minimums, maximums, and standard deviations of the variables we are interested in. The average annual sales of VC-backed firms across the panel is RMB 453.5 million. The average annual exports and sales from new products are RMB 102 million and RMB 88 million, respectively. The increases in the annual sales, exports, and sales from new products are also presented. The average increase in annual sales is RMB 104 million, accounting for 22.9% of the average annual sales. By contrast, the average increases in exports and sales from new products of VC-backed firms are RMB 27 million (26.4% of average annual exports) and RMB 20 million (23.2% of the average annual sales from new products), respectively. In addition, each VC-backed firm has been granted 7.44 patents annually on average. Finally, among 1613 observations of VC-backed firms, 464 (28.77%) have been granted patents at least once. Moreover, 104 (22.41%) out of 464 observations indicate that other firms have cited the patents at least once.

Variables	Obs	Mean	SD.	Min	Max
Sales (RMB10mil)	1,613	45.353	79.750	0.508	407.524
Dif_Sales (RMB10mil)	1,415	10.388	20.492	-15.791	91.399
Exports (RMB10mil)	1,386	10.211	24.975	0	121.603
Dif_Exports (RMB10mil)	1,012	2.698	13.151	-100.018	135.501
New_Prdct (RMB10mil)	1,386	8.795	22.707	0	105.683
Dif_New_Prdct (RMB10mil)	1,012	2.042	6.796	-7.678	29.093
Patent	1,613	7.440	103.235	0	3442
Citation	1,613	0.352	0.598	0	2
VC_Entry	1,613	0.464	0.499	0	1
Firm size (1000)	1,613	1.015	1.491	0	7.500
Leverage	1,613	0.536	0.210	0.032	1.388
Firm age	1,613	10.444	11.910	0	100
State Ownership	1,613	0.095	0.293	0	1

Table 2. Summary statistics of VC-backed firms.

This table reports summary statistics for the 268 venture-backed companies in our sample for the entire period examined. We present the number of observations (*Obs*), mean (*Mean*), standard deviation (*SD*.), minimum (*Min*) and maximum (*Max*) for the variables we are interested in.

	Non-VC-backed	d Obs (all years)		cked Obs I years)	-	
Variables	Obs	Mean	Obs	Mean	Diff	T-stats
Exports	5056	2.869	1,386	10.211	-7.342***	-10.402
Dif_Exports	3601	0.365	1,012	2.698	-2.333***	-5.562
New_Prdct	5056	1.247	1,386	8.795	-7.548***	-11.949
Dif_New_Prdct	3601	0.233	1,012	2.042	-1.809***	-8.555
Patent	5869	0.166	1,613	7.440	-7.274***	-2.830
Citation	5869	0.008	1,613	0.352	-0.344**	-2.358
	Non-VC-backed O	bs in the Entry year	VC-backed Obs			
Dif_Exports	842	0.584	182	6.104	-5.520***	-3.463
New_Prdct	1174	1.055	246	10.406	-9.351***	-5.561
Dif_New_Prdct	842	0.213	182	3.342	-3.130***	-5.276
Patent	1189	0.193	268	3.892	-3.699***	-2.708
Citation	1189	0.003	268	0.299	-0.295**	-2.302
	Non-VC-backed Ob	s in the Entry+1 year	VC-backed Obs i	n the Entry+1 year		
Exports	498	2.621	139	14.519	-11.898***	-4.124
Dif_Exports	483	0.101	118	2.472	-2.371	-1.310
New_Prdct	498	1.118	139	10.142	-9.023***	-4.338
Dif_New_Prdct	483	0.131	118	1.828	-1.670***	-2.804
Patent	557	0.110	153	6.739	-6.629*	-1.727
Citation	557	0.007	153	0.810	-0.803*	-1.640

Table 3. Differences between VC-backed and non-VC-backed firms in innovation#.

This table shows the differences in innovation output between VC-backed firms in our sample and non-VC-backed firms in our randomly drawn control group. We report the total number of observations (*Obs*), as well as the average (*Mean*) of exports (*Exports*), increase of exports (*Dif\_Exports*), new product sales (*New\_Prdct*), increase of new product sales (*Dif\_New\_Prdct*), the number of newly granted patents (*Patent*), and the increase in patent citations (*Citation*) for each group of firms over the entire period examined, the year of VC entry, and the year after VC entry. We also present the differences between the two groups of firms (*Diff*) and the T-statistics. *Exports, Dif\_Exports, New\_Prdct* and *Dif\_New\_Prdct* are RMB 10 mil. \*\*\*: 1% significance; \*\*: 5% significance; \*: 10% significance.

Table 3 reports the *t*-test results for the differences in commercialized and technological innovation outputs between VC-backed and non-VC-backed firms. We compare the two groups of firms using the onset of the VC investment. Results show that VC-backed firms have 4.87 times as much export and approximately 9.86 times as much sales from new products as non-VC-backed firms in the VC investment year. Furthermore, VC-backed firms have a significantly higher number of patents than non-VC-backed ones. The number of patents granted to VC-backed firms in the year of investment averages 3.89, whereas the number granted to non-VC-backed ones averages 0.19. Moreover, a significantly higher number of the patents of VC-backed firms have been cited than that of non-VC-backed firms. Lastly, we also observe gaps between VC-backed firms and their non-VC -backed counterparts regarding the increases in exports and sales from new products when the venture investment was made. More importantly, all the observed differences in exports, sales from new products, and the number of newly granted patents have persisted for at least two years after the venture investment was made.

## 4. Findings: the effects of VC investment and firm innovation

## 4.1 VC investment and firm innovation

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Our first question is whether VC-backed firms outperform non-VC-backed firms in terms of innovation outputs. The regression model we estimate is the following:

$$y_{-} = \alpha + \beta VC_{-}Dummy_{i} + \gamma Z_{-} + \delta_{j} + \eta_{m} + \theta_{t} + \varepsilon_{-}$$
(1)

	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
VC_Dummy	2.385***	1.698***	1.695***	2.507***
	(0.419)	(0.164)	(0.124)	(0.269)
Firm size	0.737***	0.346***	0.075***	0.137***
	(0.095)	(0.038)	(0.019)	(0.039)
Leverage	-0.238	-0.297	0.024	-0.987**
-	(0.517)	(0.236)	(0.203)	(0.500)
Ln (Firm age)	-0.440**	0.046	0.111*	0.059
-	(0.198)	(0.088)	(0.066)	(0.177)
State Ownership	0.382	0.266	-0.193	-1.124**
	(0.484)	(0.221)	(0.165)	(0.475)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-5.018**	-1.302	-4.572***	-5.708***
	(2.159)	(0.875)	(0.256)	(0.616)
Ν	4607	4607	7475	7475
R-sq	0.0537	0.0966		
Wald Chi-sq			448.10	168.86
<i>P</i> -value	0.000	0.000	0.000	0.000

Table 4. Venture Investment and	Innovation Outputs of Firms.
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This table reports the relationship between VC investment and firm innovation estimations. Models (1) and (2) are linear regressions, while Models (3) and (4) are Negative Binomial regressions for panel data. The dependent variables are the increase of exports of a firm in a given year (*Dif\_Exports*), the increase of new product sales of a firm in a given year (*Dif\_New\_Prdct*), the number of newly granted patents of a firm in a given year (*Patent*) and the increase in patent citations of a firm in a year (*Citation*). *VC\_Dummy* is a dummy variable equal to 1 if the firm is backed by VC and 0 if otherwise. Ln (*Firm Age*) is the age of a firm in a given year in a natural logarithm format. *Firm size* is measured by the total number of employees of the firm in a given year. State *Ownership* is the ratio of state-owned stake divided by the total equity of a firm in a given year. Province fixed effects, Industry fixed effects, and Year fixed effects are controlled. Values in parentheses are standard errors; \* = p < 0.1; \*\* = p < 0.05; \*\*\* = p < 0.01.

where  $y_{it}$  is firm *i* innovation output in year *t*, including *Dif\_New\_Prdct*, *Dif\_Exports*, *Patent*, *and Citation*, **a** we discussed before, *VC\_Dummy*<sub>i</sub> helps separate VC backed firms from non-VC-backed counterparts.  $\beta$  is the estimated coefficient capturing the impact of venture investment on firm innovation. *Z*<sub>it</sub> is a vector of firm-level characteristics we control for, and it includes firm size, firm age, *leverage and ownership structure*. We also incorporate a series of control variables for unobserved heterogeneity at the provincial level (by using regional fixed effects  $\delta_i$ ) and at the industry level (by using industry fixed effects  $\eta_m$ ), and for time trends in firm innovation activities (by using year fixed effects  $\theta_t$ ).

Table 4 shows the results of the regressions specified in Equation (1), which help to compare innovation outputs of VC-backed and their non-VC-backed counterparts. Models (1) and (2) present the linear regressions for firm commercialized innovation outputs measured by the increase of sales from new products and exports. Models (3) and (4) report the count data model estimations (negative binomial regressions) on technological innovation outputs of the firms measured by newly approved patent counts and the increase of citations of the firms' patents. We have controlled year, industry, and regional fixed effects for all the regression models.

The coefficients of **VC\_Dummy** are constantly significantly positive across Models (1) to (4), implying that VC-backed firms outperform non-VC-backed ones in innovation as measured by all the different approaches. Model (1) shows the increase in the annual exports of VC-backed firms is higher than that of non-VC-backed counterparts by RMB 23.9 million, and Mode (2) presents that the increase in sales from new products of VC-backed firms is higher than that of their non-VC-backed firms by RMB 17 million yearly. Lastly, Model (3) shows that VC-backed firms annually have 1.7 more newly granted patents than non-VC-backed firms, representing 43.7% of the number of newly granted patents of the VC-backed firms at the time of receipt the venture investment.

Overall, Table 4 shows a significant and positive relationship between venture investment and innovation outputs of entrepreneurial firms in China. However, identification concerns remain despite using a matched group of firms as the basis of our estimations and firm-level panel data that may help us rule out the effects of region, industry, and time-specific factors. The primary concern is whether the innovation outperformance of VC-backed firms is driven by VC investment or some other unobservable factors. Several missing variables, aside from VC involvement, may contribute to the improved performance of firms after VC investments are made. These variables include the personality of entrepreneurs, the human resource of the firms, and the market opportunity for VC-backed firms, which may affect the R&D investment and the innovation outputs of firms. If these factors co-exist with venture investment, the effects of venture investment found in Table 4 may be inflated.

We address the identification concern with unobservable variables by employing a two-stage least squares (2SLS) estimation procedure to identify venture investment effects. We employ an instrumental variable to predict the probability for a firm to be backed by venture investment in the first stage estimation and then test the effects of the VC investment after the independent variable is instrumented. The instrumental variable is the historical importance of traditional Chinese lineage value measured by the total number of genealogies in logarithm format (denoted as Genealogies) that appeared in a city before 1949. Genealogy information is obtained from http://ouroots.nlc.cn/, an online database covering 30,581 genealogies nationwide constructed by the National Library of China. It is well known that lineage groups play an essential role in the social life of Chinese society, especially in Southern China. As a unique type of community organization, lineage groups coordinate and protect local residents in traditional China (Fei and Fei 1953; Freedman 1966). In addition, such lineage groups with intensive interpersonal relationships and close ties have a high degree of trust and better internal coordination within the community (Coleman 1990; Putnam 2000). Specifically, studies have evident that informal finance has been crucial in business activities (Tsai 2004; ; Ma and Yang 2011;). Moreover, Tsai (2004) discovers that informal finance in some regions substitutes formal finance in China. In China case, it is very hard to access external finance for entrepreneurial firms, especially for R&D-oriented ones that are engaged with a high level of uncertainty and information issues. Therefore, social trust plays an even more critical role in investing in such projects. We expect informal finance to substitute VC investment for high-tech SMEs in regions with a strong impact on the traditional lineage value, particularly for the early-staged projects. Although the lineage system, as an important institution in Chinese societies, has been eliminated by the Chinese Communist Party since the early 1950s, regions with deep roots of the lineage culture would have survived through the radical political changes (Greif and Tabellini 2015). Therefore, we expect to observe a negative correlation between the number of genealogies that appeared before 1949 in a city and the probability of a firm being backed by VC investment. Meanwhile, the historical importance of the traditional lineage system should not directly affect individual firms' innovation in contemporary China. Therefore, we suggest this is a valid IV for our study.

Table 5 presents the results of the 2SLS estimations. Panel A shows the first stage estimations, in which we regress **VC\_Dummy** on the set of independent variables, including our instrumental variable. The first stage regressions in Panel A confirm that **Genealogies** is a statistically qualified instrumental variable because of its significant and negative correlation with **VC\_Dummy** for all the estimates. Panel B of Table 5 shows the results of the second stage regressions. The instrumented **VC\_Dummy** is significantly and positively correlated with all the innovation output measurements. These results are consistent with the results in Table 4, indicating that the differences in the innovation outputs between VC-backed and non-VCbacked firms are driven by venture investment. In sum, using the two-stage Heckman estimation has enabled us to identify the causal impact of VC investment on firm innovation.

The results of the 2SLS regressions confirm the effects of VCs on both the commercialized and technological innovation outputs in China, supporting hypothesis 1a. These findings are consistent with some existing studies (e.g. Kortum and Lerner 2000; Hellmann and Puri 2000; Mann and Sager 2007; Lockett et al. 2008; Bertoni, Croce, and DAdda 2010), which find positive effects of VC investment

	(1)	(2)	(3)	(4)
Panel A	VC_Dummy	VC_Dummy	VC_Dummy	VC_Dummy
Genealogies	-0.076***	-0.076***	-0.019***	-0.019***
	(-5.450)	(-5.450)	(-6.401)	(-3.891)
Constant	-0.708***	-0.708***	0.226***	0.226***
	(-29.819)	(-29.819)	(10.927)	(10.927)
Ν	4607	4607	4037	4037
P-value	0.000	0.000	0.000	0.000
Panel B	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
VC_Dummy	1.996***	1.570***	2.262***	2.731***
	(3.935)	(5.957)	(6.538)	(45.828)
Firm size	0.570***	0.335***	0.005	-0.111***
	(9.654)	(11.037)	(0.182)	(-4.566)
Leverage	0.095	-0.131	0.105	0.340***
	(0.222)	(-0.596)	(1.099)	(3.251)
In(Firm age)	-0.358**	0.018	0.038	-0.026
	(-2.306)	(0.224)	(1.244)	(-0.817)
State Ownership	-0.040	0.198	-0.045	-0.177**
	(-0.107)	(1.037)	(-0.542)	(-2.074)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-0.955	0.433	-2.301***	-2.267***
	(-1.139)	(1.006)	(-9.961)	(-8.580)
Ν	4607	4607	4037	4037
<i>R</i> -sq	0.154	0.165		
Wald Chi-sq			1011.44	4112.33
<i>P</i> -value	0.000	0.000	0.000	0.000

Table 5. Two-Stage panel regressions on VC investment and innovation outputs.

This table presents the two-stage estimations for the effects of VC investment in firm innovation output. Panel A reports the first stage of estimations, in which the dependent variables across the four models are VC\_Dummy, a dummy variable equal to 1 if the firm is backed by VCs, and 0 if otherwise. The instrumental variable is the total number of genealogies that appeared in a city before 1949 in logarithm format (*Genealogies*). Panel B reports the second stage estimations, in which the independent variables are the instrumented VC\_Dummy and the dependent variables are measurements for firm innovation output, i.e. the increase of exports of a firm in a given year (*Dif\_Exports*), the increase of new product sales of a firm in a given year (*Dif\_New\_Prdct*), the number of newly granted patents of a firm in a given year (*Patent*) and the increase in patent citations of a firm in a year (*Citation*). The control variables of estimations shown in Panel A are the same as those in Panel B. Ln (*Firm Age*) is the age of a firm in a given year in a natural logarithm format. *Leverage* is the total liability divided by the total assets of a firm in a given year. *State Ownership* is the ratio of state-owned stake divided by the total equity of a firm in a given year. Province fixed effects, Industry fixed effects, and Year fixed effects are controlled. Values in parentheses are *t*-statistics; \* p < 0.1; \*\* p < 0.05; \*\*\* p < 0.01.

on innovation. However, our estimation results contradict those of studies that find limited or no impact of VC investment on firm innovation, mainly in Europe (Bottazzi and Da Rin 2002; Engel and Keilbach 2007; Arvanitis and Stucki 2014; Mayer, Schoors, and Yafeh 2005). We suggest that the severe financial constraints faced by SMEs and the strong incentives provided by the state for corporate innovation in China play an important role for VCFs in stimulating firm innovation.

## 4.2 Do VCs select more innovative firms?

In the previous subsection, we confirm the positive relationship between venture investment and innovation outputs of firms. This subsection tries to detangle the ex-ante and ex-post effects of venture investment on innovation. We conduct logit regressions with a set of cross-sectional data on the year before the VC investment is made to determine whether VCs choose to invest in more innovative firms. The regression specification is the following:

$$\log[\mathbf{p}_{i,t}/(1-\mathbf{p}_{i,t})] = \alpha + \beta X_{i,t-1} + \gamma Z_{i,t-1} + \delta_j + \eta_m + \theta_t + \varepsilon_{i,t}$$
(2)

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	(1)	(2)	(3)	(4)
	VC_Dummy	VC_Dummy	VC_Dummy	VC_Dummy
Dif_Exports	0.048**			
	(0.021)			
Dif_New_Prdct		0.356***		
		(0.115)		
Patent			0.564***	
			(0.127)	
Citation				1.362***
				(0.465)
Firm size	0.482***	0.778***	0.361***	0.457***
	(0.179)	(0.219)	(0.099)	(0.070)
Leverage	-1.636**	-1.734**	-1.837***	-1.213***
	(0.764)	(0.801)	(0.521)	(0.324)
Ln (Firm age)	0.828**	0.694*	0.389**	0.091
	(0.356)	(0.368)	(0.172)	(0.109)
State Ownership	-1.721*	-1.969*	-0.534	-0.884*
	(1.007)	(1.054)	(0.541)	(0.456)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-4.234	-4.192	-2.096	-2.700
	(2.887)	(3.060)	(2.045)	(1.693)
Ν	300	300	632	632
Pseudo R-sq	0.3381	0.3978	0.2896	0.1894
<i>P</i> -value	0.000	0.000	0.000	0.000

This table reports the Logit regressions for VC investment selection. The dependent variables across the four models are VC\_Dummy, a dummy variable equal to 1 if the firm is backed by VCs, and 0 if otherwise. The independent variable is the increase of exports of a firm in a given year (*Dif\_Exports*), the increase of new product sales of a firm in a given year (*Dif\_New\_Prdct*), the number of newly granted patents of a firm in a given year (*Patent*) and the increase in patent citations of a firm in a year (*Citation*) in Models (1), (2), (3) and (4), respectively. Ln (*Firm Age*) is the age of a firm in a given year in a natural logarithm format. *Leverage* is the total liability divided by the total assets of a firm in a given year. State *Ownership* is the ratio of state-owned stake divided by the total equity of a firm in a given year. Province fixed effects, Industry fixed effects, and Year fixed effects are controlled. Values in parentheses are standard errors; \* = p < 0.1; \*\* = p < 0.05; \*\*\* = p < 0.01.

where  $p_{i, t}$  is the probability of firm *i* being backed by VC,  $Log[p_{i, t}/(1-p_{i, t})]$  is the logarithm of the odds.  $X_{i}$ , t-1 measures firm-level innovation output, and it could be one of *Dif\_New\_Prdct*, *Dif\_Exports*, *Patent*, *and Citation*.  $Z_{i}$ , t-1 is the same vector as we define in Equation (1).  $\delta_{j}$ ,  $\eta_{m}$ , and  $\theta_{t}$  are used to control regional fixed effects, industry fixed effects, and year fixed effects, respectively.

Table 6 presents the logit regression results in which VC\_Dummy is the dependent variable. In Models (1) to (4), we separately place the innovation variables into the estimates. Model (1) shows that VC Dummy is significantly related to the annual increase in a firm exports, indicating that a larger increase of exports increases the probability of a firm being selected by VCs in China. Specifically, if the annual change of export is increased by 6 million (approximately 10% of the mean of Dif\_Exports for VC-backed firms in the VC investment year), it may elevate the probability of such a firm being selected by VCs by 4.1%. Model (2) reports a significant and positive relationship between the annual increase of sales from new products and venture investment, suggesting that firms are more likely to be backed by VCs if they have track records in bringing more new products to the market. These results are consistent with the findings of Helmann and Hellmann and Puri (2000) that were derived from the US market. Specifically, if the increase of annual sales from new products of the firm is increased by 3 million from its mean (approximately 10% of the mean of Dif\_New\_Prdct for VC-backed firms in the VC investment year), it may elevate the probability of such a firm to be selected by VCs by 14.4%. Models (3) and (4) report the relationship between venture investment and technological innovation outputs. We observe significant and positive relationships between Patent and VC Dummy and between Citation and VC Dummy, which suggests that those firms with track records of having more technological innovation outputs tend to be selected by VCs. One more newly granted patent of the firm increases the probability of such a firm being backed by VCs by 8.17%. The quality of these patents is also a decisive factor, and one more citation of these patents increases the probability of these firms being backed by VCs by 18.1%.

We also control for the firm leverage ratio, firm size, age, and state share. Firm size is significantly and positively correlated with *VC Dummy*, which implies that VCs tend to choose larger firms in China with everything else being equal. Furthermore, the leverage ratio is significantly and negatively correlated with *VC Dummy*, suggesting that firms with a higher leverage ratio may have a lower chance for selection by VCs. Finally, firm age is significantly and positively associated with *VC Dummy* as shown in Models (1) to (3), and the state ownership is significantly and negatively correlated with *VC Dummy* as reported in Models (1), (2) and (4).

Although the logit regression results show that the increase of exports and sales from new products, the number of newly granted patents and increased patent citations of firms are strongly and positively correlated with the probability of being backed by VCFs, we cannot conclude that the ex-ante project selection causes these findings. Other unobservable factors may have affected these results. An alternative explanation for these findings is that VCs attract rather than select firms with more innovations. For instance, only entrepreneurial firms with a high level of innovation may seek venture investment because such firms are associated with more uncertainties that diminish the chance to seek other means of external finance. Furthermore, the entrepreneurs who approach VCs may be very innovative and possess the vision and knowledge of the potential added value of VC investment. We cannot rule out these alternative explanations because we have no information on which entrepreneurs seek VC investment or which projects are rejected by VCs.

To address this concern, we use in-depth interviews with VCs to explore the causal relationship between VC investment selection and innovation of firms. The interviews were conducted with 37 VCs in China between 2005 and 2006. Guo and Jiang (2013) discussed the interview methodology and sampling strategy. The interview results show that the ex-ante project assessment process is highly selective and results in a very high rejection rate. According to the interviews with 37 VCs from 34 VCFs, on average, only 1.3 out of the 100 business plans submitted to VCs have received investment in China.<sup>12</sup> VCs also devote much of their effort to ex-ante project selection. More than 85% of the interviewed VCs suggest that assessing projects before making investment decisions takes more than three months. These VCs visit entrepreneurial firms more than six times before making investment decisions. VCs assess projects in various ways during the due diligence process, such as visiting the customers and suppliers of firms, tracking the business and personal records of entrepreneurs and management teams, consulting experts in relevant markets, assessing technological improvements, and consulting accounting and auditing firms.

The interview results also reveal that VCs consider the technological improvements of entrepreneurial projects as important aspects when making investment decisions. As shown in Table A1, 12 out of the 39 criteria are related to the product and market of entrepreneurial firms. Meanwhile, VCs consider the demonstrated market acceptance and the proprietary of the product or service as the top two most important criteria in terms of the characteristics of the product or service of the project. In addition, the market share growth rate is ranked as the second most important factor among the 39 criteria in project screening identified by VCs. We also ask the VCs to list the essential criteria without which they will reject projects regardless of other aspects. As shown in Table A2, the market growth, market acceptance, and proprietary of products are listed as essential criteria. These three aspects are reflected by sales growth from new products and patent-related measurements in our regression estimations.

#### Table 7. The PSM Sample.

Variables	Obs	Mean	SD.	Min	Max
Panel A: Summary Statistics of PSM sample					
Dif_Exports	4,047	0.947	5.579	-14.012	40.745
Dif_New_Prdct	4,047	0.506	4.376	-13.032	36.229
Patent	7,002	1.730	26.806	0	1161
Citation	7,002	0.088	1.587	0	76
Firm size	7,002	0.936	2.293	0.015	14.471
Leverage	7,001	0.488	0.256	0.009	1.127
Ln (Firm age)	6,999	2.172	0.836	0	4.605
State Ownership	7,002	0.065	0.246	0	1

Panel B: T-test in one year before the VC Entry year for PSM sample

	Non-VC-b	acked Obs	VC-ba	cked Obs
Variables	Obs	Mean	Obs	Mean Diff T-stats
InSales	988	12.070	201	12.087 -0.017-0.184
Dif_Sales	988	0.597	201	0.666 -0.069-0.962
Dif_Exports	667	1.734	135	2.030 -0.296-0.336
Dif_New_Prdct	659	0.599	135	0.549 0.051 0.347
Patent	1,095	2.995	224	4.746 -1.750-0.787
Citation	1,095	0.349	224	0.353 -0.004-0.086

This table presents the basic information for the PSM control group. Panel A reports the summary statistics of the PSM control group during the entire examination period. We report the total number of observations (*Obs*), mean (*Mean*), standard deviation (*SD*.), minimum (*Min*) and maximum (*Max*) for all the variables of interest. Panel B presents the t-tests (*T-stats*) of the difference (*Diff*) in terms of variables of interest for the VC-backed firms and the PSM control group one year before the VC entry. Firm innovation is measured by the increase of exports (*Dif\_Exports*), the increase of new product sales (*Dif\_New\_Prdct*), the number of newly granted patents (*Patent*), and the increase in patent citations (*Citation*) of a firm in a given year. *Firm Size* is measured by the total number of employees of a firm in a given year in natural logarithm format; *Leverage* is the total liability divided by the total assets of a firm in a given year; *State Ownership* is the ratio of state-owned stake divided by the total equity of a firm in a given year.

The interview results suggest that VCs exert considerable efforts in ex-ante project selection and that the selection criteria are consistent with the aspects that we have defined in our regression analysis results. However, we do not claim that the ex-ante project selection process is the sole explanation for our statistical examinations. Instead, we suggest that our interview findings may help us identify the mechanisms that underlie our regression estimates.

In sum, companies with better track records in both commercialized and technological innovation outputs have a higher probability of gaining funding from VCs in China. These findings support our hypothesis 1b and are consistent with those of studies that suggest VC investment supports more firms of more uncertainty in the US, Israel and Taiwan (Elango et al. 1995; Gupta and Sapienza 1992; Avnimelech, Kenney, and Teubal 2004; Lahr and Mina 2016). However, such results differ from many findings from Europe, where VC investment tends to choose firms of less uncertainty (Jeng and Wells 2000; Mayer, Schoors, and Yafeh 2005) and has limited ex-ante effects on firm growth (Bertoni, Croce, and DAdda 2010). In particular, our findings on the ex-ante effects of VC investment on both types of firm innovation in China may have two implications. First, venture experts consider both the realized commercialized innovation and technological innovation when making the investment decision to deal with the information issues and uncertainty in China. Second, although information issues in China are serious, venture experts and entrepreneurs foresee great potential for R&D-oriented SMEs to capitalize on their innovations because of the strong state incentives provided to corporate innovation.

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## 4.3 Ex-post effects of VC investment on innovation

The results from the previous subsections confirm that VC-backed firms outperform non-VC-backed firms in terms of innovation and that part of such outperformance comes from the VC selection efforts. This subsection examines whether VCs' post-investment monitoring and supporting efforts add value to their portfolio companies. Specifically, we focus on the difference-in-difference estimates of innovation outputs of VC-backed and non-VC-backed firms.

As discussed in Subsection 4.2, VCs select firms with more innovation outputs. To capture the difference-in-difference effects, we need to control selection biases. We construct a new control group of non-VC-backed firms using the PSM methodology, in which we match firms with different dimensions (Rosenbaum and Rubin 1983; Chemmanur, Krishnan, and Nandy 2011). In our context, we specifically choose the PSM approach proposed by Rosenbaum and Rubin (1983) because this matching method eliminates a significant proportion of the systematic difference in baseline characteristics between treated and untreated subjects than the stratification on propensity score or the covariate adjustment using such a score does (Austin et al. 2007). The matched firms must be in the same industry (at the two-digit level), the same location, and have a similar level of exports, sales from new products and patents in the year before VCs back them. With the help of one-to-five, nearest-neighbor PSM, we identify non-VC-backed firms in the control group.

In total, we have a sample of 1328 firms in the PSM control group. The summary statistics of the PSM control group during the whole examination period are presented in Panel A of Table 7. Panel B of Table 7 presents the t-tests of the variables of interest for the VC-backed firms and the PSM control group one year before the VC entry. It shows that there is no significant difference between the two groups regarding annual sales, an annual increase of exports, an annual increase of sales from new products, newly granted patents, and an annual increase of patent citations, indicating that firms in the PSM control group are similar to VC-backed firms before the VC entry.<sup>13</sup> The PSM method helps alleviate selection biases caused by observed factors.

Based on this control group matched by propensity scores, we estimate the ex-post effects of venture investment. The regression model is as follows:

$$y_{it} = \alpha + \beta VC_D ummy_i + \beta_1 VC_E ntry_{it} + \beta_2 VC_P ost_{it} + \gamma Z_{it} + \delta_j + \theta_t + \eta_m + \varepsilon_{it}$$
(3)

where  $y_{it}VC_Dummy_iZ_{it}\delta_j$ ,  $\eta_m$ , and  $\theta_t$  are defined exactly the same as they are in Equation (1).  $VC\_Entry_{it}$  helps separate the whole period into before and after the VC investment.  $VC\_Post_{it}$  is the interaction term of  $VC\_Dummy_i$  and  $VC\_Entry_{it}$ , and its coefficient ( $\beta_2$ ) captures both the betweengroup and within-group differences (i.e. the difference-in-difference) in terms of the effects of venture investment on firms' innovation output. A significantly positive coefficient of  $VC\_Post_{it}$ indicates that VC-backed firms experience a magnified increase in post-investment innovation compared with non-VC-backed firms.

Table 8 shows the estimated innovation outputs of VC-backed and non-VC-backed firms matched using the PSM approach. We observe a significant and positive relationship between *VC\_Post* and the increase in annual exports and sales from new products in Model (1) and (2), respectively. Such results indicate that firms experience a magnified increase in both exports and sales from new products after VC investment. After the VC investment, the treatment effect is increased by RMB 11.5 million for the annual increase in export and RMB 12.1 million for the annual increase in sales from new products. In addition, Model (3) shows that *VC\_Post* is significantly and positively associated with the number of newly granted patents. This result indicates that firms experience magnified improvements in their technological innovations after VC investment. Specifically, after VC investment, the treatment effect of VC investment in terms of the number of newly granted patents increases by 0.385.

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Table 8. Ex-post effects of VC investment (PSM sample	Table 8
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	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
VC_Post	1.145***	1.213***	0.385*	-0.393
	(0.442)	(0.383)	(0.235)	(0.325)
VC_Dummy	0.710**	1.033***	2.388***	2.676***
- ,	(0.340)	(0.294)	(0.167)	(0.320)
VC_Entry	-0.453*	-0.081	0.242*	0.084
- ,	(0.235)	(0.204)	(0.142)	(0.253)
Firm size	0.554***	0.325***	0.511***	0.229***
	(0.039)	(0.034)	(0.026)	(0.022)
Leverage	0.736**	0.047	-0.115	-0.262
5	(0.354)	(0.306)	(0.234)	(0.427)
ln(Firm age)	-0.383***	-0.006	0.364***	0.311**
	(0.122)	(0.106)	(0.070)	(0.154)
State Ownership	-0.137	0.402	-0.282	-2.232***
	(0.353)	(0.305)	(0.209)	(0.427)
Province FE	Y	Y	Ŷ	Ŷ
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-0.171	-2.750**	-2.405***	-5.329***
	(1.813)	(1.175)	(0.183)	(0.584)
Ν	4954	4954	8565	8565
R-sq	0.081	0.063		
Wald Chi-sq			642.44	249.03
P-value	0.000	0.000	0.000	0.000

This table reports the regression estimations for the ex-post effects of VC investment on firm innovation based on the PSM sample. Models (1) and (2) are linear regressions, while Models (3) and (4) are Negative Binomial regressions for panel data.  $VC\_Dummy$  is a dummy variable equal to 1 if the firm is backed by VC and 0 if otherwise.  $VC\_Entry$  equals 0 for the period before the VC investment is made and 1 for the period after the investment is made. The value of this variable for the firms in the control group is determined by their pairs in the VC-backed group.  $VC\_Post$  is the interaction term of  $VC\_Entry$  and  $VC\_Dummy$ . Dependent variables and control variables are the same as those in Table 4. Values in parentheses are standard errors; \* = p < 0.1; \*\* = p < 0.05; \*\*\* = p < 0.01.

The above estimates suggest that the outperformance of VC-backed firms in terms of commercialized and technological innovation outputs is further magnified. We observe ex-post effects of venture investment on exports, sales from new products, and the number of newly granted patents in China. These results support hypothesis 1c and contradict the findings of Lahr and Mina (2016), who find no ex-post effects of VC investment on firm patenting activities in the US. We suggest that two primary reasons may drive the differences. First, as we have discussed, the information problem in China is so severe that VCFs must monitor their portfolio companies after investment and set milestones for commercialization of innovations and patenting activities to validate and certify the future financial promise of these companies. Second, R&D-oriented firms, especially those in the private sector, may face much more severe financial constraints than their counterparts in developed economies that the availability of VC investment has significantly long-lasting effects on them.

## 5. IPR protection, characteristics of VCFs and VC effects

## 5.1 IPR protection and the impact of VC investment

This subsection explores the heterogeneous effects of VC investment focusing on IPR protection. The regression models are as follows:

$$y_{it} = \alpha + \beta VC_D ummy_i + \beta_1 IPR_{jt} + \beta_2 VC_D ummy_{i*} IPR_{jt} + \gamma Z_{it} + \delta_j + \theta_t + \eta_m + \varepsilon_{it}$$
(4)

where  $y_{it}$ , VC\_Dummy<sub>i</sub>,  $Z_{it}\delta_j$ ,  $\eta_m$ , and  $\theta_t$  are defined exactly the same as they are in Equation (1).  $IPR_{jt}$  measures location *j* IPR protection at time *t*.

As discussed in Section 2, we expect to observe that VC effects on firm innovation are stronger in regions with better IPR institutions in China. Table 9 presents the results of the regression estimations. In these regressions, we add a dummy variable, i.e. VC\_Dummy, to differentiate VC-backed firms from non-VC-backed firms. We further add two more variables, i.e. the measurements of IPR protection and the interaction term between **VC Dummy** and the measurements of IPR protection. With the interaction terms included in the regression model, we aim to capture the sensitivity of the VC effects on firm innovation to IPR institutions. Panel A presents the results in which IPR protection is measured by Infringement\_Filed, and Panel B reports the results in which IPR protection is measured by Infringement\_Closed, respectively. As shown in Panel A, the coefficients of VC Dummy are constantly and significantly positive across all the estimations for firm innovation measured by all ways, confirming the positive effects of VC investment in firm innovation. At the same time, the interaction terms between Infringement Filed and VC Dummy are significantly and negatively associated with most of the variables measuring firm innovation, including the increase of sales from new projects and exports and the number of newly granted patents. We observe similar results when IPR protection is measured by the ratio of the number of infringement cases closed over the total number of patents granted in a province each year. Such results suggest that the VC effects on firm innovation are weakened when the patent infringement rate is high. As discussed earlier, we conduct a set of robustness checks using an alternative IPR protection measurement, namely the IPR index published by the CMI between 1998 and 2007. The results are presented in Table A3. It shows that results are similar to those reported in Table 9.

The results shown in Table 9 and Table A3 support hypothesis 2, which predicts VC effects are strengthened on firm innovation when IPR protection is strong. These findings suggest that with weak IPR protection in China in general that competitors can easily exploit the benefits of innovation, the marginal returns from stronger IPR protection are high, consistent with the theories of Griliches, Hall, and Pakes (1991) and Ueda (2004). However, our empirical results suggest that the arguments of Bessen and Maskin (2009) regarding the benefits of imitation do not seem to be valid in China when the overall IPR protection is weak.

#### 5.2 Characteristics of VCFs and the impact of VC investment

In this subsection, we investigate how the impact of VC investment depends on the characteristics of VCFs. The regression models are as follows:

$$y_{it} = \alpha + \beta VCF EXP_i + \gamma Z_{it} + \delta_j + \theta_t + \eta_m + \varepsilon_{it}$$
(5)

$$y_{it} = \alpha + \beta VCF_Ownership_i + \gamma Z_{it} + \delta_i + \theta_t + \eta_m + \varepsilon_{it}$$
(6)

where  $y_{it}Z_{itx}\delta_j$ ,  $\eta_m$ , and  $\theta_t$  are defined exactly the same as they are in Equation (1). The expertise of the lead VCF is measured by VCF\_EXP<sub>i</sub>. The value of this variable is defined as 0 for non-VC-backed firms. It could be either VCFs' age or the total number of closed investment deals. The ownership structure of the lead VCF is measured by VCF\_Ownership<sub>i</sub>. The value of this variable is equal to 0 for non-VC-backed firms.

Table 10 reports the regression results for the relationship between firm innovation and the experience of VCFs. Panel A shows the effects of VCFs' age on firms' innovation outputs. Both **VC\_Age1** and **VC\_Age2** are significantly and positively related to all the innovation output measurements. Panel B focuses on the effects of VCFs' experience, measured by the total number of closed investment deals at the time of investment. Similarly, we observe that both the **VC\_Comp1** and **VC\_Comp2** are constantly and positively associated with the firm innovation measured by all means. The above results indicate that regardless of the experiences of the lead VCF, VC-backed firms generate higher commercialized and technological innovations compared with non-VC-backed firms, consistent with the results shown in Tables 4 and 5. However, we observe that the effects of

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#### Table 9. Sensitivity of VC effects to IPR protection.

	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
Panel A: IP protection is measured by In	fringement Filed			
VC_Dummy	2.797***	1.987***	1.930***	2.009***
	(0.517)	(0.228)	(0.149)	(0.118)
Infringement_Filed	0.794	0.504	-0.125	-0.547
VC_Dummy*Infringement_Filed	(0.663) —2.903**	(0.375) –1.311**	(0.372) —0.756*	(0.398) 0.341
	(1.160)	(0.636)	(0.448)	(0.485)
Firm size	0.791***	0.279***	0.073***	0.136***
	(0.114)	(0.050)	(0.022)	(0.020)
Leverage	-0.135	-0.265	-0.093	-0.152
	(0.584)	(0.291)	(0.227)	(0.202)
In(Firm age)	-0.617***	0.018	0.148**	0.153**
State Ouwenship	(0.233)	(0.111)	(0.076)	(0.065)
State Ownership	0.811 (0.573)	0.411 (0.289)	-0.173 (0.190)	-0.150 (0.190)
Province FE	(0.373) Y	(0.289) Y	(0.190) Y	(0.190) Y
Year FE	Ŷ	Ý	Y	Ý
Industry FE	Ý	Ŷ	Ŷ	Ŷ
Constant	-5.095	-2.167	-4.282***	-3.367*
	(3.900)	(1.641)	(0.303)	(2.037)
N	3427	3427	5683	5683
R-sq	0.079	0.093		
Wald Chi-sq			390.84	740.25
<i>P</i> -value	0.000	0.000	0.000	0.000
	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
Panel B: IP protection is measured by In	frinaement Closed			
VC Dummy	2.797***	1.987***	1.930***	2.009**
· - <u>-</u> )	(0.517)	(0.228)	(0.149)	(0.118)
Infringement_Closed	1.166	0.580	-0.069	-0.625
<b>5</b> –	(0.850)	(0.481)	(0.461)	(0.499)
VC_Dummy*Infringement_Closed	-3.333**	-1.666**	-1.290**	0.234
	(1.469)	(0.806)	(0.584)	(0.615)
Firm size	0.793***	0.279***	0.074***	0.137**
	(0.114)	(0.050)	(0.022)	(0.020)
Leverage	-0.139	-0.264	-0.100	-0.150
	(0.584)	(0.291)	(0.227)	(0.202)
In(Firm age)	-0.616***	0.017	0.152**	0.154**
Charles Oursearch in	(0.233)	(0.111)	(0.075)	(0.065)
State Ownership	0.816 (0.573)	0.412 (0.289)	-0.173 (0.189)	-0.150 (0.190)
Province FE	(0.373) Y	(0.289) Y	(0.189) Y	(0.190) Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-5.059	-2.170	-4.261***	-3.736
Constant	(3.898)	(1.641)	(0.306)	(2.175)
N	3427	3427	5683	5683
R-sq	0.079	0.093		2000
Wald Chi-sq			391.85	740.26
P-value	0.000	0.000	0.000	0.000

This table reports the regression estimations for the sensitivity of VC effects to IPR protection. Models (1) and (2) are linear regressions, while Models (3) and (4) are Negative Binomial regressions for panel data. *VC\_Dummy* differentiates the treated and control groups (between groups). *IPR protection is* measured by two different variables. *Infringement Filed* is the ratio of the total number of patent infringement cases filed over the total number of patents granted in a province each year, and *Infringement Closed* is the ratio of the total number of patent infringement cases filed over the total number cases closed over the total number of patents granted in a province each year. The higher the ratios are, the lower the IPR protection is in a region. The interaction term of *IPR variables* and *VC\_Dummy* (*VC\_Dummy\*IPR*) is also included. Dependent variables and control variables are the same as those in Table 4. Values in parentheses are standard errors; \* = p < 0.1; \*\* = p < 0.05; \*\*\* = p < 0.01.

VCFs' experience differ for commercialized and technological innovations. Specifically, we observe that the coefficients of *VC\_Age 2* and *VC\_Comp2* are constantly much larger than those of *VC\_Age1* and *VC\_Comp1* in estimations on the commercialized innovation output, i.e. the increase of new

	(1) Dif_Exports	(1) (2)	(2)	(3)	(4)
		Dif_New_Prdct	Patent	Citation	
Panel A					
VC_Age1	1.636***	1.240***	1.627***	2.648***	
_ 3	(0.551)	(0.214)	(0.145)	(0.317)	
VC_Age2	3.108***	2.141***	1.767***	2.383***	
-	(0.543)	(0.212)	(0.147)	(0.307)	
Firm size	0.736***	0.347***	0.072***	0.138***	
	(0.095)	(0.038)	(0.019)	(0.039)	
Leverage	-0.238	-0.295	0.021	-0.997**	
5	(0.516)	(0.236)	(0.203)	(0.504)	
ln(Firm age)	-0.437**	0.048	0.116*	0.051	
	(0.198)	(0.088)	(0.066)	(0.178)	
State Ownership	0.365	0.255	-0.196	-1.092**	
	(0.483)	(0.220)	(0.165)	(0.476)	
Province FE	Y	Y	Ŷ	Y	
Year FE	Ŷ	Ŷ	Ŷ	Ŷ	
Industry FE	Y	Y	Y	Y	
Constant	-4.991**	-1.288	-4.573 ***	-5.677***	
	(2.156)	(0.872)	(0.256)	(0.619)	
V	4607	4607	7475	7475	
R-sq	0.0553	0.0996			
Wald Chi-sq			448.06	168.24	
P-value	0.000	0.000	0.000	0.000	
Panel B		0.000	0.000	0.000	
VC Comp1	2.116***	1.370***	1.813***	2.922***	
	(0.566)	(0.219)	(0.145)	(0.324)	
/C_Comp2	2.622***	1.995***	1.572***	2.148***	
re_compz	(0.535)	(0.210)	(0.147)	(0.313)	
Firm size	0.739***	0.349***	0.079***	0.142***	
initi size	(0.095)	(0.038)	(0.019)	(0.039)	
Leverage	-0.236	-0.292	0.011	-1.082**	
Levelage	(0.517)	(0.236)	(0.203)	(0.510)	
n(Firm age)	-0.440**	0.047	0.102	0.033	
in(i iiii uge)	(0.199)	(0.088)	(0.066)	(0.180)	
State Ownership	0.375	0.253	-0.188	-1.030**	
State Ownership	(0.484)	(0.221)	(0.165)	(0.473)	
Province FE	(0.404) Y	(0.221) Y	(0.105) Y	(0.473) Y	
Year FE	Ý	Ŷ	Ý	Ý	
ndustry FE	Y	Y	Y	Ý	
Constant	-4.990**	-1.259	-4.579***	-5.738***	
Lonstant	(2.161)	(0.875)	(0.255)	(0.622)	
V	4607	4607	(0.255) 7475	(0.822)	
	4607 0.0542	4607 0.0982	/4/0	/4/5	
R-sq Wald Chi sa	0.0342	0.0962	157 75	170.00	
Wald Chi-sq	0.000	0.000	452.25	170.29	
P-value	0.000	0.000	0.000	0.000	

Table 10. The effects of VCFs' experience on innovation outputs.

This table reports the effects of VCFs' experience on firm innovation. Panel A presents the results in which VCFs' experience is measured by the age of a VCF. *VC\_Age1* equals one if the lead VCF is younger than 10 years when the VC-backed firm gained its first VC investment and equals zero if otherwise. *VC\_Age2* equals one if the lead VCF is older than ten years when the VC-backed firm gained its first VC investment and equals zero if otherwise. *VC\_Age2* equals one if the lead VCF is older than ten years when the VC-backed firm gained its first VC investment and equals zero if otherwise. Panel B reports the results in which VCFs' experience is measured by the number of deals closed by the VCF. *VC\_Comp1* equals one if the lead VCF has closed fewer than 100 venture deals when the investment in a given entrepreneurial firm has been concluded and zero if otherwise. *VC\_Comp2* equals one if the lead VCF has closed 100 or more venture deals when the investment in a given entrepreneurial firm has been concluded and equals zero if otherwise. Dependent variables and control variables are the same as those in Table 4. Models (1) and (2) for both panels are linear regressions, while Models (3) and (4) are Negative Binomial regressions for panel data. Values in parentheses are standard errors; \* = p < 0.1; \*\* = p < 0.05; \*\*\* = p < 0.01.

product sales and the increase of exports of a firm. For instance, Models (1) and (2) of Panel A show that firms backed by VCFs younger than ten years gain RMB 16.4 and 12.4 million more increase in exports and new products sales, respectively. However, firms backed by VCFs older than ten years enjoy 31.1 and 21.4 million more increase in exports and new products sales, respectively. Similar trends are found with the estimations on the effects of VCFs' experience measured by the total deals closed before the specific investment. These results suggest that the more experienced the lead VCF is, the more likely the VC-backed firms generate more commercialized innovation output. However, we observe different patterns from the estimations for firms' technological innovation. We find that the coefficients of VC\_Age2 and VC\_Comp2 are smaller than those of VC\_Age1 and VC\_Comp1 in most of the estimates on technological innovation output measured by the number of newly granted patents and the increased frequency of patent citations, expect for Model (3) of Panel A. Such results suggest that although VC-backed firms generate a higher number of patents and their patents are cited more than non-VC-backed ones, firms backed by more experienced VCFs generate fewer technological innovations than those backed by less experienced ones. A potential explanation is that with more experience in the Chinese market, VCs realize that patents may not be well protected under the weak enforcement of IRP, and they focus more on monitoring and supporting firms to commercialize their innovative ideas as soon as possible than those VCFs with less experience. Meanwhile, VCFs with less experience may focus more on the number of patents and citations as they are more observable and easier to measure than the market performance of the innovations. In all, these results are partially consistent with the prediction of hypotheses 3a and 3b and the findings from developed economies in the existing literature (e.g. Nahata 2008; Krishnan et al. 2011).

Table 11 reports the regression results for the relationship between firm innovation and the ownership structure of VCFs, which show that **PVCF** and **GVCF** are constantly and positively associated with the firm innovation measured by all means. However, the coefficients of **PVCF** are

	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
Panel A				
PVCF	3.156***	1.683***	1.683***	2.539***
	(0.520)	(0.185)	(0.141)	(0.303)
GVCF	1.816**	1.496***	1.877***	3.120***
	(0.875)	(0.304)	(0.208)	(0.399)
Firm size	0.585***	0.396***	0.110***	0.213***
	(0.101)	(0.037)	(0.024)	(0.047)
Leverage	-0.307	-0.240	0.091	-0.946*
5	(0.515)	(0.224)	(0.211)	(0.535)
ln(Firm age)	-0.363*	0.060	0.104	-0.032
<b>3</b>	(0.201)	(0.084)	(0.070)	(0.187)
State Ownership	-0.131	0.124	-0.075	-0.001
·	(0.494)	(0.215)	(0.179)	(0.443)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-4.309*	-2.109**	-4.558***	-5.704***
	(2.221)	(0.829)	(0.269)	(0.675)
Ν	4408	4408	7146	7146
R-sq	0.052	0.102		
Wald Chi-sq			394.58	153.76
P-value	0.000	0.000	0.000	0.000

This table reports the effects of VCFs' ownership on firm innovation. *GVCF* is a dummy variable that equals one if more than 50% of the VCF is owned by the state and zero if otherwise. *PVCF* is also a dummy variable that equals one if the state owns less than 50% of the VCF and zero if otherwise. Dependent variables and control variables are the same as those in Table 4. Models (1) and (2) are linear regressions, while Models (3) and (4) are Negative Binomial regressions for panel data. Values in parentheses are standard errors; \* = p < 0.1; \*\* = p < 0.05; \*\*\* = p < 0.01.

constantly much larger than those of **GVCF** in estimations on the commercialized innovation output, i.e. the increase of new product sales and the increase of exports of a firm. For instance, Models (1) and (2) show that firms backed by PVCFs enjoy RMB 31.6 and 16.8 million more increase in exports and new products sales, respectively. However, firms backed by GVCFs gain 18.2 and 15 million more in exports and new products sales, respectively. These results show that firms backed by PVCFs generate more commercialized innovation output, supporting hypothesis 3d.

In contrast, we observe that the coefficients of **PVCF** are smaller than those of **GVCF** in the estimates on technological innovation output measured by the number of newly granted patents and the increased frequency of patent citations. Specifically, Models (3) and (4) show that firms backed by PVCFs generate 1.68 and 2.54 more patents and citations, while those backed by GVCFs generate 1.88 and 3.12 more patents and citations. These findings support hypothesis 3c that firms backed by GVCFs outperform those backed by PVCFs in technological innovation.

The results shown in Table 11 are in some sense consistent with the findings of several studies which find that government VC programs or GVCFs have positive effects on firm innovation either at industry or firm-level in the USA and Australia (Kortum and Lerner 2000; Cumming 2007; Colombo and Murtinu 2017). However, they contradict other studies' discoveries that find VC investment has limited or even negative effects on firm innovation in Europe and Canada (e.g. Cumming and MacIntosh 2006; Da Rin, Nicodano, and Sembenelli 2006; Brander, Egan, and Hellmann 2010; Bertoni and Tykvová 2015). We suggest that, on the one hand, the severe financial constraints and the strong state incentives for corporate innovation determine that the equity investment from either GVCFs or PVCFs is ultimately important for firms to initiate R&D activities that help them enhance innovation output. On the other hand, the strong political and social pressure carried by GVCFs, as well as the lack of incentives and investment capacity, may prompt GVCFs to focus on patent activities of the companies they invest in, as patents are more visible, easier to measure and validate, and more likely to be recognized by the higher authorities compared to the commercialized innovation.

## 6. Conclusion

This study examines the contributions of VC investment to innovation outputs of entrepreneurial firms in China. By analyzing firm-level panel data, we find that VCs contribute to the commercialized and technological innovation outputs of entrepreneurial firms in China. We use 2SLS estimations to address identification issues, and our results have remained robust. These findings are consistent with some existing studies (e.g. Kortum and Lerner 2000; Hellmann and Puri 2000; Mann and Sager 2007; Lockett et al. 2008; Bertoni, Croce, and DAdda 2010), which find positive effects of VC investment on innovation. However, our estimations' results contradict those of studies that find limited or no impact of VC investment on firm innovation, mainly in Europe (Bottazzi and Da Rin 2002; Engel and Keilbach 2007; Arvanitis and Stucki 2014; Mayer, Schoors, and Yafeh 2005). We suggest that the severe financial constraints faced by SMEs and the strong incentives provided by the state for corporate innovation in China play an important role for VCFs in stimulating firm innovation. Moreover, we distinguish the selection and ex-post effects of VC investment and confirm that VC investment has significant impacts on the innovation of entrepreneurial firms in two ways. First, VCFs in China select more innovative firms. Second, VC-backed firms experience a magnified improvement in their innovation after the VC investment. These results are partially consistent with Lahr and Mina (2016), who find only selection effects but no ex-post effects of VC investment on firm patenting activities in the US. We suggest that with more severe information problems in China, VCFs may have to put more effort both before and after the investment is made than their counterparts in the US, thereby having both selection and

treatment effects on their portfolio companies. Additionally, R&D-oriented SMEs in China may face much more severe financial constraints than their counterparts in the USA, and the availability of VC investment has significantly long-lasting effects on them.

We also observe that the effects of VCs are heterogeneous, depending on both the institutional environments and the features of VCFs. VC effects on firm innovation significantly stronger when the IPR protection is stronger. At the same time, firms backed by more-experienced VCFs generate more commercialized innovation outputs but fewer technological innovation outputs than those backed by less-experienced VCFs. Finally, firms backed by GVCFs are more productive in patenting activities but less productive in generating commercialized innovation outputs than those backed by PVCFs. The findings in this study evident that the impact of VC investment varies under different institutional environments. In particular, IPR institutions, the institutional environments for controlling information issues, and government engagement in the VC market play an important role in determining the effects of VC investment on firm innovation.

This study contributes to the literature on VC investment in several aspects. This study is the first to systematically estimate the contribution of VC investment to the innovation of entrepreneurial firms in China, where financial and legal systems are significantly different from those of Western countries. It extends the findings of previous studies by exploring factors that influence the effects of VC investment with a focus on both external institutional environments and the features of VCFs. Using a difference-in-difference approach based on cross-regional variations within the same country, this study is among the first that links private equity investment, IPR institutions, and firm innovation, ruling out the potential biases caused by cross-country studies. This study, therefore, contributes to the debating literature on IPR institutions, R&D investment and innovation with evidence from the Chinese private equity market (Gallini 2002; Branstetter and Sakakibara 2002; Branstetter 2006; Qian 2007; Ang, Cheng, and Wu 2014; Fang, Lerner, and Wu 2017). Furthermore, following Chemmanur, Krishnan, and Nandy (2011) and Guo and Jiang (2013), the current study is among the first that attempts to answer a puzzling question earlier raised by Kortum and Lerner (2000): 'If VC-backed firms outperform non-VC-backed firms, does the advantage come from ex-ante project selection or monitoring and control after the investment is made?' Finally, we add the existing studies on the relationship between the characteristics of VCFs and the impact of VC investment by providing evidence on how different experiences and ownership of VCFs affect different types of firm innovation in various ways.

Some limitations of this study and potential questions for future research are worthwhile to mention. Above all, the estimations of VC investment and innovation are just up to 2007 because of the constraints of data sources. China VC market and the innovation systems have experienced significant changes since then, and more updated data may help explore more insights regarding the institutional impacts on the effect of VC investment on innovation. However, it is important to note that the theoretical nature of the research questions focused on in this study and the corresponding empirical findings (i.e. the impact of VC investment on firm innovation and the mechanisms by which VC investment works under different institutional environments that provide different incentives to entrepreneurs and venture experts) are time- and context independent. Therefore, we suggest that such limitations should not have significant impacts on the contributions of this study. In addition, we can only focus on manufacturing firms in this study because of the data constraints. It is ideal if the effects of VC investment on the service sector can be studied in future research. Finally, other institutional factors and other features of VCFs (e.g. the relationship between VCFs and local and central governments, the governance efficiency of VCFs, etc.) and entrepreneurial firms' characteristics should be examined in the future.

This study has significant implications for policymaking and business practice. By identifying different conditions under which the impact of VC investment vary, this study suggests that the factors including financial constraints entrepreneurs face, the information issues associated with

investing in high-tech SMEs, the IPR institutions, the government engagement in R&D activities as well as the experience of VCFs may all influence the effects of VC investment on firm innovation. Policymakers need to consider the local contexts when they make decisions for stimulating the local VC market to maximize the impact of VC investment (Lerner and Nanda 2020). Meanwhile, given that the Chinese VC market is the fastest growing one in the world and the innovation capacity and sustainability of the Chinese economy is one of the most critical concerns of the globe, understanding the private equity market and the innovation system in this country is ultimately important for policymakers to consider how they should prepare for the potential dominance or the uncertainty associated with the financial markets and the innovation system of this country. Finally, this study provides helpful information for investors and entrepreneurs regarding what conditions they may gain more in terms of financial outcomes and technological aspects of innovation.

#### Notes

- Source: Annual Reports on Venture Capital Investment in China 2011 released by Zero2IPO (https://report. pedata.cn/list\_1\_0\_253\_0\_0\_0.html) and 2019 Preqin Global Private Equity and Venture Capital Report (https:// www.preqin.com/insights/global-alternatives-reports/2019-preqin-global-private-equity-and-venture-capitalreport/24905)
- 2. Source: Hurun 2019 Global Unicorn List (https://www.hurun.net/EN/Article/Details?num=A38B8285034B)
- 3. Source: China Unicorn Report 2018 released by Zero2IPO in 2019
- 4. Examples of such programs include the 863 program (the State High-Tech Development Plan), the Torch program, the Innovation Fund for Small and Medium Technology-based Firms and the InnoCom program, among many others.
- 5. Source: 2019 China business climate survey report released by the American Chamber of Commerce in China (https://www2.deloitte.com/content/dam/Deloitte/au/Documents/international-specialist/deloitte-amcham -2019-china-business-climate-survey-report-bilingual-190301.pdf)
- 6. ASIFP data are available for the years between 1998 and 2009. However, we chose not to use the data for 2008 and 2009 because of two major reasons. First, the data quality for years 2008 and 2009 is poor. For example, the legal person ID of firms, which is the only information for identifying the same firm accurately for the panel data, is not available in the data for 2008. In addition, we noted missing variables in the data for years 2008 and 2009. One missing variable is state-owned capital, which is one of our control variables. Important financial information, such as sales income, is missing as well. Additionally, the year 2009, the number of observations dropped significantly (from more than 400 K in 2008 to 320 K in 2009). We suspect that the sample does not represent the full sample of the above-scale manufacturing firms in China. All existing studies in China that used this dataset did not adopt the data in 2008 and 2009 to ensure the consistency of the estimations (e.g. Hsieh and Klenow, 2009; Guariglia, Liu, and Song 2011; Brandt, Zhang, and Zhang 2012). Second, we did not use the data for years 2008 and 2009 because of the financial crisis in 2008. Many other external shocks, including the crisis itself and the sequential stimulus packages after 2008, could cause noises in our estimations. Hence, we chose to limit our data between 1998 and 2007 for the examinations.
- 7. In the first Chinese Economic Census conducted in 2004, the amount of the total sales for all industrial firms was RMB 218 billion, whereas that of the total sales for all ASIFP firms was RMB 196 billion.
- 8. In China, enterprises with employment of less than 300 people or annual sales of less than RMB 20 million are classified as small enterprises. Enterprises with employment of less than 20 people or annual sales of less than RMB 3 million are classified as micro enterprises.
- 9. For more detailed methodology and the codes of patent matching of the NBER Patent Data Project, please refer to https://sites.google.com/site/patentdataproject/Home.
- 10. We use 'stem names' to conduct the matching in order to capture potential missed cases during matching using 'standard names' (we might not have exhausted all expressions of the legal entity identifiers and converted them into standard identifiers when we created 'standard names').
- 11. According to our data sorting on VentureXpert database, there are about 540 manufacturing firms gaining their first round of VC investment between 1998 and 2007.
- 12. The interviewees were asked about the percentages of the business plans submitted to them that eventually gain the investment in the interview. According to the interviews with the 37 VCs from 34 VCFs, the minimum was 0.6% while the maximum was 2.5%. The mean success rate was 1.3%.

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13. We also conduct balancing tests for each variable of interest by year (results are provided by request). The t-statistics of the balance tests show that firms in control group matched by PSM are similar to VC-backed firms at the time of VC backing in all the relevant aspects that may predict the probability of a firm being picked up by VCs.

## **Disclosure Statement**

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## Appendix

Table A1. Ex-ante project assessment criteria of VCs in China.

Table A1. Ex-ante project assessment Criteria of VCs in China.		
Project selection criteria: Likert Scale: 0–4	Mean	SD
Group I: Personality of entrepreneur. The entrepreneur:		
1. is honest enough.	3.68	0.475
2. is capable of sustained intense effort.		0.485
3. is able to evaluate and react to risks well.		0.544
4. articulates in discussing venture.		0.409
5. attends to details.		0.551
6. has a personality compatible with mine.		0.870
7. has a rich social network.	3.03	0.388
Group II: Capability of the entrepreneur. The entrepreneur:		
8. is thoroughly familiar with the market targeted by the project.		0.448
9. has demonstrated leadership ability in the past.		0.410
10. has a track record relevant to the venture.		0.514
11. was referred to me by a trustworthy source.		0.618
12. has overseas educational and working experience.		0.933
13. I am already familiar with the entrepreneur reputation.	2.03	0.627
Group III: Characteristics of the product or service		
14. The product is proprietary or can otherwise be protected.	2.94	0.629
15. The product enjoys demonstrated market acceptance.	3.26	0.511
16. The product has been developed to the point of a functioning prototype.	2.18	0.576
17. The product may be described as 'high tech'.		0.702
18. The product has excellent export potential.		0.460
19. The product or service is complementary to our other portfolios.	2.09	0.621
Group IV: Characteristics of the market of the product or service		
20. The target market enjoys a significant growth rate.	3.71	0.462
21. The venture will stimulate an existing market.	2.35	0.485
22. The venture is in an industry with which I am familiar.	2.06	0.547
23. There is little threat of competition during the first three years.	2.82	0.387
24. The venture will create a new market.		0.489
25. The market size is scalable.	3.18	0.576
Group V: Financial considerations with this project		
26. I require a return equal to at least ten times my investment within 5–10 years.	3.24	0.606
27. I require an investment that can easily be liquid (e.g. taken public or acquired).	2.94	0.422
28. I require a return equal to at least ten times my investment within at least five years.	2.76	0.431
29. I will not be expected to make a subsequent investment.	1.94	0.600
30. I will not participate in later rounds of investment.	1.24	0.606
31. It is easy to find further investors or bank loans for the project.	2.38	0.511
Group VI: Geographical considerations with this project		
32. The project is located in the capital city or other major cities in China.	2.26	0.511
33. The project is located within 50 miles of my office.	1.24	0.431
34. It is easy to access needed human resources in the location.	3.00	0.492
35. Local public policy is friendly to SMEs and the venture industry.	2.97	0.460
Group IV: Features of the management team. (Please score 1 for the single item below that you suggest the es	sential c	one for
the venture to go forward.)	E 00/	
36. The project is initiated by one person, and he/she has relevant experience on the idea.	5.9% 8.8%	
<ul><li>37. The project is initiated by more than one person, all having similar relevant experience.</li><li>38. The venture is initiated by more than one person, constituting a functionally balanced management team.</li></ul>		
39. None of the above factors are essential for the venture to go forward.	26.5%	
	20.070	

This table reports the results of interviews on project selected criteria reported by VCs in China. Thirty-four interviewees from 37 VCFs were asked to rank each criterion on a Likert scale from 0 to 4 expressing the level of agreement.

	Number	%
1. The entrepreneur is thoroughly familiar with the market targeted by the project.	25	73.5
2. The entrepreneur is capable of sustained intense effort.	23	67.6
3. The entrepreneur is honest enough.	22	64.7
4. The target market enjoys a significant growth rate.	20	58.8
5. The entrepreneur is able to evaluate and react to risks well.	13	38.2
6. I require a return equal to at least ten times my investment within 5–10 years.	11	32.4
7. The product enjoys demonstrated market acceptance.	10	29.4
8. The market size is scalable.	9	26.5
9. The product is proprietary or can otherwise be protected.	6	17.6
10. Local public policy is friendly to SMEs and the venture industry.	4	11.8

This table reports the interviews with the essential project selection criteria identified by the VCs. Thirty-four interviewees from 37 VCFs were asked to list the essential criteria without which they will reject projects regardless of other aspects. In total, ten essential criteria were identified.

Table A3. Sensitivi	ty of VC effects to IPR	protection (IPR	protection is measured b	y IPR_Index).
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	(1)	(2)	(3)	(4)
	Dif_Exports	Dif_New_Prdct	Patent	Citation
VC_Dummy	2.063***	1.007***	1.471***	1.907***
	(0.558)	(0.227)	(0.161)	(0.132)
IPR_Index	-0.014	-0.011	0.000	0.002
	(0.028)	(0.014)	(0.009)	(0.008)
VC_Dummy*IPR_Index	0.029	0.065***	0.020**	0.014*
_ , _	(0.032)	(0.015)	(0.009)	(0.009)
Firm size	0.733***	0.340***	0.072***	0.133***
	(0.095)	(0.038)	(0.019)	(0.018)
Leverage	-0.216	-0.267	0.038	-0.010
5	(0.518)	(0.236)	(0.203)	(0.184)
In(Firm age)	-0.434**	0.049	0.103	0.101*
	(0.199)	(0.088)	(0.065)	(0.057)
State Ownership	0.405	0.302	-0.185	-0.260
·	(0.485)	(0.221)	(0.164)	(0.163)
Province FE	Ŷ	Ŷ	Ŷ	Ŷ
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y
Constant	-4.981**	-1.216	-4.281***	-3.613***
	(2.163)	(0.875)	(0.279)	(0.119)
Ν	4607	4607	7475	7475
<i>R</i> -sq	0.054	0.101		
Wald Chi-sq			479.83	942.80
<i>P</i> -value	0.000	0.000	0.000	0.000

This table reports the regression estimations for the sensitivity of VC effects to IPR institutions. Models (1) and (2) are linear regressions, while Models (3) and (4) are Negative Binomial regressions for panel data.  $VC\_Dummy$  equals one if the firm is a VC-backed one and zero if otherwise. *IPR\_Index is* the score indicating the weighted average for the number of patents filed and approved per R&D professionals in a province in a given year. The interaction term of *IPR\_Index* and *VC\_Dummy* (*VC\_Dummy\*IPR\_Index*) is also included. Dependent variables and control variables are the same as those in Table 4. Values in parentheses are standard errors; \* = p < 0.1; \*\*\* = p < 0.05; \*\*\* = p < 0.01.